

# 9 **FLUOROSCOPIC EXPOSURE CONTROL AND IMAGE QUALITY**

Fluoroscopic imaging systems are by far some of the most complex systems in the radiology or diagnostic imaging department. Most hospitals and the majority of service engineers do not have the appropriate equipment to properly set up and evaluate video systems. In general, there is a significant lack of understanding in the field of radiology concerning how video systems work and the associated problems. Even more significantly, many manufacturers provide video systems that do not conform to the EIA Standard RS-170 (Electronics Industries Association, 1957). This standard specifies the shape and composition of the video waveform. If a system does not meet these standards, then it may be impossible to interface it with generally available video equipment, e.g., with  $\frac{3}{4}$ -inch videotape recorders or TV monitors other than those provided by the fluoroscopic system manufacturer. In addition, much of the equipment that is needed to evaluate video systems must be presented with a standard signal, specified by RS-170, to function properly.

Without going into detail about the specifics of video systems and how they function and differ, we provide the QC technologist with sufficient information to carry out quality control checks on this equipment. Ideally, to set up and evaluate video systems, you need a video waveform monitor and video signal generator. Since these are not commonly available in most hospitals (in fact, most manufacturers do not supply their service engineers with this type of equipment at the present time), we will describe tests that will provide the maximum amount of information with tools that are commonly available. If you are interested in delving further into video systems evaluation, a video engineer (usually affiliated with televi-

sion facilities, both commercial and private) may be able to provide additional assistance and insight.

Although it is possible to use pen-type dosimeters for the evaluation of fluoroscopic systems, we would recommend the use of a direct readout digital dosimeter. Pen dosimeters are much less accurate than direct readout dosimeters, are usually rate dependent, and require that you measure the exposure time and calculate the exposure rate from the time and total exposure received. This latter problem is compounded by the fact that most fluoroscopic systems do not stabilize at the actual exposure rate immediately, causing a significant error in the measurements.

## **FLUOROSCOPIC IMAGE SIZE AND BEAM LIMITATION**

Most fluoroscopic imaging systems do not provide the radiologist with a television image of the entire input and output phosphor of the image intensifier tube. In some instances, this is intentional since the outer edges of the image intensifier exhibit many forms of image degradation including brightness fall-off and loss of resolution. In other cases, an inappropriate lens may have been chosen to couple the intensifier to the video camera or the scan size may be improperly set on the video camera. This test will allow for the determination of the exact area being imaged and allow the QC technologist to assure that all fluoroscopic systems in the department are producing images of a similar size.

Although the federal government provides regulations concerning the amount of collimation error allowed relative to the image intensifier, these regula-

tions, like all of the federal regulations, deal only with the condition of the equipment when it is initially installed. However, many states do have requirements that must be met and are usually similar to those set out by the federal government x-ray equipment certification regulations (Bureau of Radiological Health, 1980). In addition, the collimation must be adjusted and functioning properly to assure that the patient is not receiving unnecessary radiation exposure. This will ultimately reduce the amount of scatter radiation that the technologist and radiologist are exposed to in the examining room and will improve image quality.

### **MAXIMUM FLUOROSCOPIC EXPOSURE RATE**

The maximum fluoroscopic exposure rate setting is important in two respects. First, if the maximum rate is set too low, then adequate radiation will not be available to penetrate larger patients in the AP projection nor will it be available to penetrate most patients in the lateral or oblique positions. Second, if the rate is set too high, then the patient and staff will be receiving unnecessarily high radiation exposures, especially in the lateral projections or when a bolus of barium may be obscuring most of the photodetector area. Again, the federal regulations do not impact directly on the radiology department, only on the original equipment installer. However, we prefer to recommend the federally prescribed maximum radiation levels since these have been found to be quite adequate in our practice and also since many states have adopted the federal x-ray equipment certification levels as state laws.

### **STANDARD FLUOROSCOPIC EXPOSURE LEVELS**

To maintain optimum fluoroscopic image quality over an extended period of time, it is necessary to assure that the radiation levels reaching the image intensifier (and the patient) are consistent. In addition, the quality of the radiation (kVp) must be in a reasonable range with sufficient mA to produce an image with acceptable image noise. In many instances, the standard exposure rate is increased by the service engineer if the radiologist complains of a slightly noisy or mottled image. Consequently, many institutions find that their standard fluoroscopic exposure rate approaches the maximum fluoroscopic exposure rate, providing adequate fluoroscopy for the normal patient in the AP position but resulting in severely degraded images for the heavier patient or any patient in the lateral position. The appropriate balance of technical factors and video system adjustments

will assure that good-quality fluoroscopic images can be maintained at reasonable exposure rates for all but the extremely obese patient. A few patients, because of their size, cannot be adequately imaged with fluoroscopic systems without exceeding the maximum fluoroscopic exposure rates and exposing the patient and staff to high levels of radiation.

Another goal of a good quality control program in regard to fluoroscopic image systems is to provide a good-quality image at a minimum exposure level. However, adjusting exposure levels requires a good service engineer familiar with fluoroscopic systems and perhaps the advice of a diagnostic radiologic physicist. The adjustment requires the proper and delicate balancing of the kVp, mA, video gain, and optical aperture size. For example, you can reduce the exposure to the patient by increasing the camera gain and/or opening the camera aperture. However, this will result in a noisy image, with the noise being primarily quantum mottle. Another approach would be to increase the video camera gain to a maximum value but set the aperture at a reasonable level. In this case, the image will also be noisy, but the noise will result primarily from the electronic noise in the video system. In addition, if the camera is set at maximum gain, the automatic gain control will not be able to provide additional gain to compensate for the low radiation levels transmitted through an obese patient or most patients in the lateral position, thereby limiting the diagnostic information available. Consequently, by correctly selecting the proper technical factors, aperture, and gain, you can provide an image of reasonable quality at a reasonable exposure while allowing the system sufficient gain to compensate for a radiation-starved image with large patients.

Another point to consider is the elimination of grids for fluoroscopic procedures and for the production of PFS films on all patients, and for making conventional spot films in pediatric areas. In most instances where high-contrast information is present in the diagnostic image (e.g., GI studies and hip pin-nings), it is possible to eliminate grids and realize a dose reduction of up to two times (Gray and Swee, 1982). In making spot films, this allows for a reduction in exposure time, which may result in better images because of decreased peristaltic motion.

### **AUTOMATIC BRIGHTNESS CONTROL (ABC), AUTOMATIC DOSE CONTROL (ADC), AND AUTOMATIC GAIN CONTROL (AGC)**

Confused? You are not alone! Many people think that all of these controls do the same thing, i.e., provide

automatic control of the exposure, and hence of the brightness, of the final image. ABC and ADC are systems that automatically adjust the kVp and/or mA in a fluoroscopic imaging system to maintain sufficient radiation for a quality image. Since these controls are tied to the x-ray generator, it is necessary to have servo mechanisms that adjust the technical factors, a sometimes slow process especially if you are going from low to high kVp or mA. In addition, the maximum fluoroscopic exposure rate is preset so that the kVp and mA cannot exceed a certain level.

The AGC, on the other hand, is an automatic *gain* control that is an integral part of the video camera and does not affect the technical factors nor the exposure to the patient. With AGC an image will be produced even after the fluoroscopic system has reached the maximum exposure level through obese patients or in lateral projections. In this case the gain is increased, making a brighter image than would normally be possible, although the noise in the image is also increased. However, the tradeoff is that you obtain an image where the TV monitor normally would be dark. Also, in a situation where the kVp and/or mA servo mechanisms have not yet driven to the proper level, the AGC will change the camera gain to present a reasonable image while the technical factors are changing (the AGC can react in milliseconds, whereas most servo mechanisms adjust much more slowly).

In most instances, the AGC either works properly or is not functioning at all, so the tests to determine if it is functioning are quite simple. The only difficult thing is getting the system set up properly in the first place.

#### **TV MONITORS AND VIDEOTAPE AND VIDEODISC RECORDERS**

A large proportion of service calls concerning fluoroscopic image quality involve the adjustment of the TV monitor. In many cases, this is the correct approach, but in other cases it is not. It is easy to adjust the monitor to correct for problems in other parts of the system, but this does not produce good quality fluoroscopic images. For example, if the video signal from the system is too low, you can increase the brightness and contrast settings of the monitor and produce a viewable image. However, this increases the apparent mottle and electronic noise, which is sometimes compensated for by increasing the standard operating exposure level, thus also increasing the exposure to the patient and staff.

In some cases, the brightness and contrast are misadjusted during use and it is difficult to readjust

the settings to produce a pleasing image. This is best done by using a standard phantom and should not be done during patient studies. Many TV monitors have inadequate black level clamping, which causes difficulty in adjusting the contrast and brightness. In this case, if you adjust the contrast, the brightness may drift and adjustments in the brightness may change the contrast. Consequently, both controls must be adjusted simultaneously. This can be avoided by requesting a good-quality TV monitor with black level clamping. (It is interesting that, when you spend \$200,000 to \$300,000 on a fluoroscopic suite, the salesman often offers a less expensive TV monitor to save a few dollars. This is really a false savings since good quality black and white monitors cost about \$1500, a fraction of the cost of the room.)

Videotape players offer a real challenge in diagnostic radiology. The inexpensive units using  $\frac{3}{4}$ -inch cassette tapes have a significantly lower bandpass than the video systems used for fluoroscopic systems, so that reduced image quality can be expected from taped images. The newer, small format recorders, designed for home use, have even lower bandpass and should *not* be used in diagnostic radiology or any area of diagnostic imaging (such as ultrasound). Also, almost all videotape recorders available at prices less than \$5,000 do not have a means of viewing a single field with reasonable quality nor do they have the potential for slow motion replay. Note that when you are viewing a still image from a videotape recorder, the image is displayed in the field mode, i.e., only half of the TV scan lines are displayed. Therefore, in addition to a loss in resolution from a lower bandwidth, a stop-frame image from a videotape recorder has decreased vertical resolution since only half of the scan lines are being used.

If a videotape recorder is to be used in diagnostic imaging, then a good-quality black and white monitor should be purchased for replaying videotapes. Color TV monitors, such as those used for home viewing, are extremely limited in the amount of detail that can be displayed. In addition, a reasonable black and white image cannot be properly viewed on a color monitor because of the phosphor dot size and/or overlay mask used in making the CRT.

Videodisc recorders are available with the ability to provide instant replays, just like those used for professional football game broadcasts. Normally, the image can be replayed in real time (30 frames per second), or at slower frame rates and even in stop-action mode. Some of these devices are also available with removable discs, although the discs cost about \$150 each.

Videodisc recorders all have one major limitation—most cannot record more than 600 TV frames, or the equivalent of 20 seconds of video imaging at 30 frames per second. However, the slow motion and stop-action capabilities may be beneficial in diagnostic imaging and the image recorded on videodisc could then be transferred to videotape if a permanent video record is required. Both videotape and videodisc recorder images can be recorded on a multifomat or video hard-copy camera to provide a permanent hard-copy image.

### **FLUOROSCOPIC IMAGE NOISE**

The noise in fluoroscopic images can come from two sources—electronic noise and quantum mottle or noise. In a well-designed and properly calibrated fluoroscopic imaging system, the predominant noise should be quantum noise. It is important to determine which type of noise is limiting the capabilities of the system. If electronic noise is the culprit, a complete recalibration of the system is probably required.

### **IMAGE LAG**

Lag in television images is best described as a smearing of the image when the camera is rapidly panned past an object or the object is rapidly moved past the camera. Lag is also sometimes referred to as comet tailing. Lag is much greater in vidicon camera tubes as compared to the plumbicon tubes or other newer types of tubes. However, some of the newer vidicon tubes do exhibit lag characteristics similar to plumbicons, and plumbicon tube lag can be greater than that of vidicons if they are not set up properly. The primary reason for lag in a new plumbicon is a lack of light reaching the imaging surface of the tube. This can be corrected by opening the optical aperture of the camera system or by increasing radiation levels to the input of the image intensifier. However, most camera tubes will show an increase in the lag with time, becoming objectionable near the end of their useful life.

The amount of lag that is acceptable will depend on the radiologist viewing the image and the use of the fluoroscopic system. A system used for imaging orthopedic procedures, such as hip pinnings, can operate with relatively long lag, whereas a system used for placing the electrodes of a pacemaker in the heart will require a camera tube with a minimum amount of lag.

Although lag has a detrimental impact on the overall quality of the image because of its smearing effect, it can also be beneficial. Increasing lag will

tend to integrate frames of the video image and thereby reduce the apparent level of the quantum mottle. This may be beneficial where low doses are more important than imaging of rapidly moving objects. In such cases, the vidicon should be the image tube of choice.

### **SETTING AND MAINTAINING CINE AND PHOTOFLUOROSPOT (PFS) FILM CAMERA EXPOSURES**

Like all radiographic systems, the cine and PFS camera systems require attention to assure that the exposure levels remain constant. However, cine systems produce exceedingly high exposure rates (on the order of 50–75 R/min and higher) so that they warrant particular attention. Most people assume that PFS film exposures are relatively low. This may be the case if you are filming the abdomen without barium, but these exposures may be quite high (on the order of 2 to 6 rads) if the photodetector is located over a bolus of barium and the system is attempting to penetrate the barium (Gray and Swee, 1982). Consequently, both cine and PFS filming devices should be checked frequently to assure they are producing proper film densities at reasonable exposure levels. In addition, since most of these systems operate with some type of automatic exposure control or phototiming device, there is an increased possibility of system problems.

### **FLUOROSCOPIC, PHOTOFLUOROSPOT FILM, AND CINE RESOLUTION**

Resolution is directly related to the sharpness and detail in a diagnostic image. These systems are affected by focal spot size, imaging geometry, optical focus (two optical chains for each system), electronic focus of the image intensifier, and (in the case of fluoroscopy) the electronic focus of the video camera. A shift in focus of any one of the elements will degrade the image quality and resolution; if more than one element is not properly focused, the resultant image will be significantly degraded. However, many times systems may drift out of focus and the loss of information will go unnoticed if it happens slowly over a long period of time. Periodic, quantitative checks are necessary to avoid significant degradation in image quality of this nature.

### **LOW-CONTRAST FLUOROSCOPIC TEST**

Resolution normally refers to the ability to discern the presence of two or more small, high-contrast objects

in close proximity. Another important test of an imaging system involves its ability to image single, low-contrast objects. Where high-contrast resolution will be rapidly degraded by slight changes in focus, it will not be affected by increases in either electronic or quantum noise. Low-contrast images may be less affected by drifts in focus but will be significantly degraded by minor increases in noise. (In fact, slight defocus may even improve the detection of low-contrast objects since it helps to reduce the noise by integrating its effect.)

Because of the different applications of diagnostic imaging systems, it is essential that all imaging systems in diagnostic use be evaluated both for high-contrast resolution and to determine the low-contrast imaging ability.

### **VIDEO WAVEFORM MONITORING**

Video systems are some of the most complex pieces of equipment in a diagnostic imaging department and require specific tests and test instrumentation for proper setup and maintenance. The video waveform

monitor is a device similar to an oscilloscope that allows the display of individual TV lines or groups of TV lines directly from the video camera. The vertical deflection is proportional to the brightness seen on the TV monitor. A conventional oscilloscope can be used in place of a video waveform monitor, although this makes it somewhat more difficult to carry out the appropriate tests.

The evaluation of the video waveform will allow you to determine if the components of the waveform are at the correct voltages and to determine the amount of inherent contrast in the image intensifier-video system. Also, you can check to determine if the grid and x-ray tube are appropriately aligned.

In our institution, we use the waveform monitor for a more extensive evaluation of the video system than we describe here. However, most of these tests are still in the developmental stages, and we are still collecting baseline data concerning the expected performance levels of video systems in diagnostic imaging. We do anticipate extensive use of the video waveform monitors in quality control and in the servicing of video systems in the future.

# PROCEDURES

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## 9.1. FLUOROSCOPIC IMAGE SIZE AND BEAM LIMITATION

### Purpose

1. To assure that a fluoroscopic imaging system is displaying the entire area it was designed to display. [**Note:** The image area can be lost by improper image tube sizing, underscanning of the output phosphor of the image tube by the TV camera, or an improperly sized blanking ring.]
2. To prevent unnecessary patient exposure resulting from irradiation of an area larger than the image receptor.
3. To meet BRH beam limitation requirements.

### Equipment Needed

1. Collimator alignment template with markings in either centimeters (preferred) or inches
2. A nonscreen film holder and film, or a ready-pack nonscreen film. If your system has a 6-inch (15-cm) image intensifier tube, an 8 × 10-inch (20 × 25-cm) film will be large enough, but a 9-inch (23-cm) intensifier will require a 10 × 12-inch (25 × 30-cm) film.
3. Masking or any other nongumming tape [**Note:** Avoid white hospital tape because of the residue left behind when the tape is removed.]

### Procedure—To Determine Image Size and Collect Data for Beam Limitation

1. Place the fluoroscopic tower at its maximum height, with the collimators completely open.
2. Fluoroscopically center and tape the template to the input of the image intensifier, or spot film device if one is present, and prevent contact with the image tube. If your system has a 9-inch (23-cm) intensifier, place the long axis of the template across the length of the table to permit access for the 10 × 12-inch (25 × 30-cm) film.
3. Place the nonscreen film between the template and the intensifier or spot film device (Figure 9.1).
4. Measure and record the distance from the tabletop to the input of the image intensifier.
5. Fluoroscope and record the image size in both dimensions from the TV monitor or mirror if your system is a direct view system (Figure 9.2). [**Note:** Image intensifier sizing is the only factor that will affect sizing in direct viewing systems.]
6. If your system has a photofluorospot camera or cinecamera, record the template at approximately 50 kVp and the lowest operating mA possible (Figure 9.2c). [**Note:** If overexposure occurs repeat the exposure with a uniform-density phantom in the beam.]
7. After all the image size data have been collected, or after approximately 2 minutes of fluoroscopy time, remove and process the nonscreen film.
8. If you have a multimode intensifier repeat this procedure in all modes.
9. If your system has a photofluorospot camera or cine camera with exact framing where the entire image is seen on the film, you will be able to determine the sizing of the image tube by measuring the area exposed on the spot film, using the markings of the template. In general, most image intensifiers do not display an area as large as is quoted by the manufacturer. Normally, a 6-inch (15-cm) intensifier will be 5.5 to 5.9 inches (14 to 15 cm) in diameter and a 9-inch (23-cm) intensifier will be 7.8 to 8.7 inches (20 to 22 cm). To prevent an unnecessary service call, check with the manufacturer for the exact image intensifier tube size. By comparing the photofluorospot data with the fluoroscopic data, you can determine if the TV tube and blanking ring are properly sized. Direct viewing systems should, of course, display the entire image tube. If your system does not have a camera, you should display an area no smaller than 1 cm less than that specified by the manufacturer.

### Procedure—Fluoroscopic Beam Limitation

1. A film of the actual beam size at maximum tower height has already been exposed while collecting the image size data. A second optional film can be made and measured at the minimum tower height, following the same procedure.

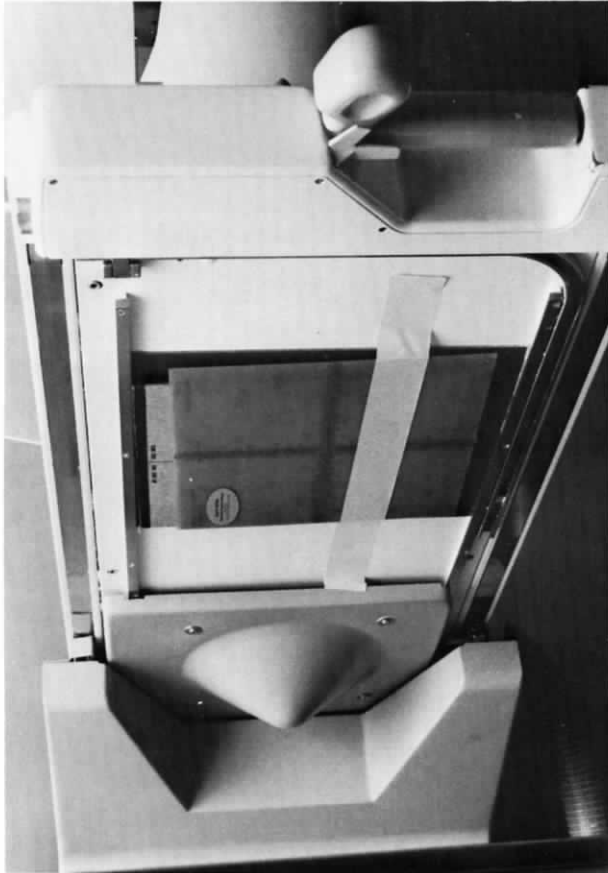


Figure 9.1. Fluoroscopic image size and beam limitation test setup.

2. Because the BRH regulations are tied to the source-to-image distance (SID), the distance from the x-ray focal spot to the tabletop must be determined. In some types of equipment, the x-ray tube can be reached to make this measurement, but in most cases you must find this information in the equipment manuals.
3. Compare the area exposed on the film with the area seen on the fluoroscopic image at both the minimum and maximum tower heights, and in all modes if your system is a multimode system, to determine if the beam limitation system is meeting acceptance limits (Figure 9.3).

#### Problems and Pitfalls

1. Conventional spot film devices, which prevent direct contact with the image tube, will somewhat reduce the appearance of the image size, but at maximum tower height the effect will be minimal if the system is sized properly.
2. Some types of image intensifiers have very little range in their sizing adjustment so you may not be able to change the sizing as much as you might wish.
3. Any change in image intensifier sizing will affect the focus of the intensifier. In some cases you may have to sacrifice sizing to be able to focus the system properly.
4. Image intensifiers that are grossly undersized lose gain because there is less minification; resizing may allow a reduction in the standard exposure rate.
5. Increasing the TV scan or blanking ring may uncover some alignment problems, which must be corrected.

#### Acceptance Limits

1. Image intensifiers should be sized to the maximum area that still allows proper focus.
2. TV tube scanning and blanking rings should be adjusted to cover the entire output phosphor of the image tube. **[Note:** This procedure may display a white ring around the outside of the image.]
3. Try to keep the total area loss to 1 cm or less than the actual size of the image intensifier.

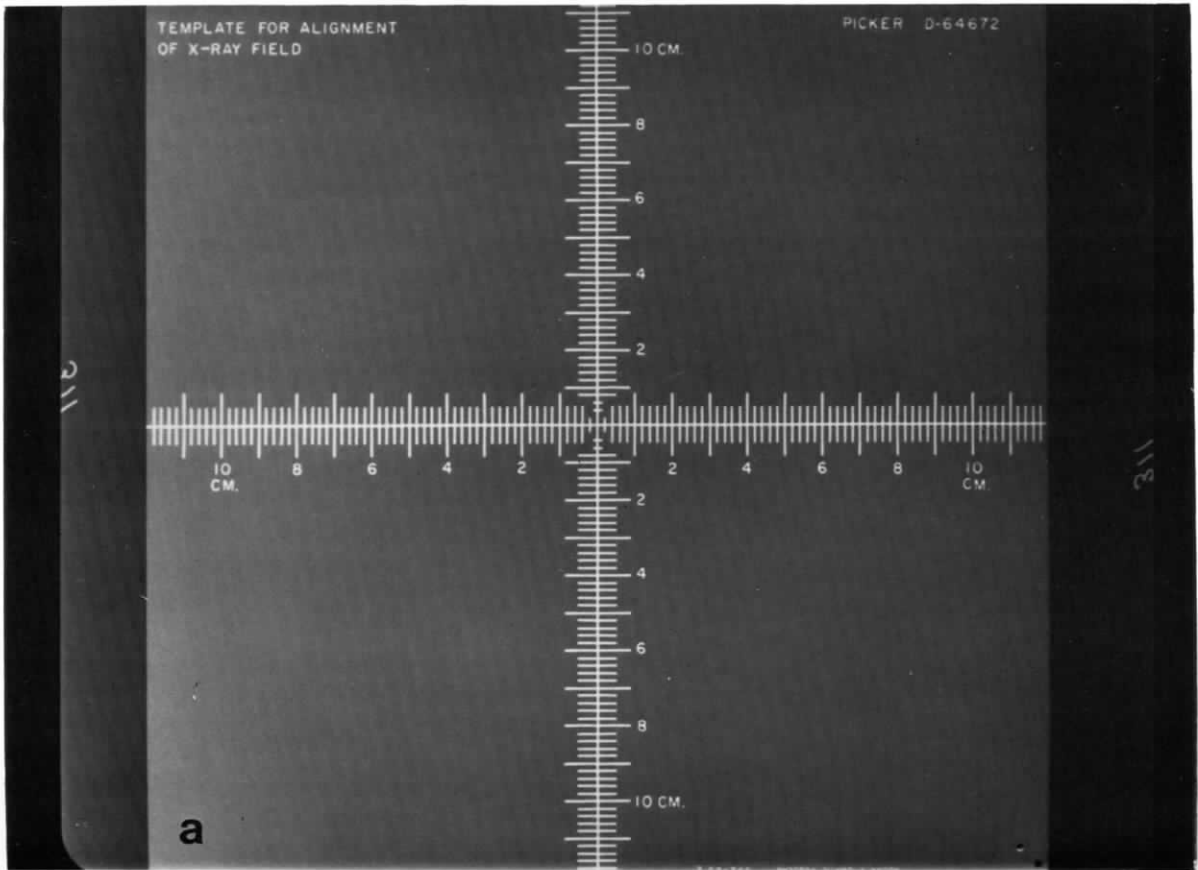


Figure 9.2a. Radiograph of the fluoroscopic image size and beam limitation test template.

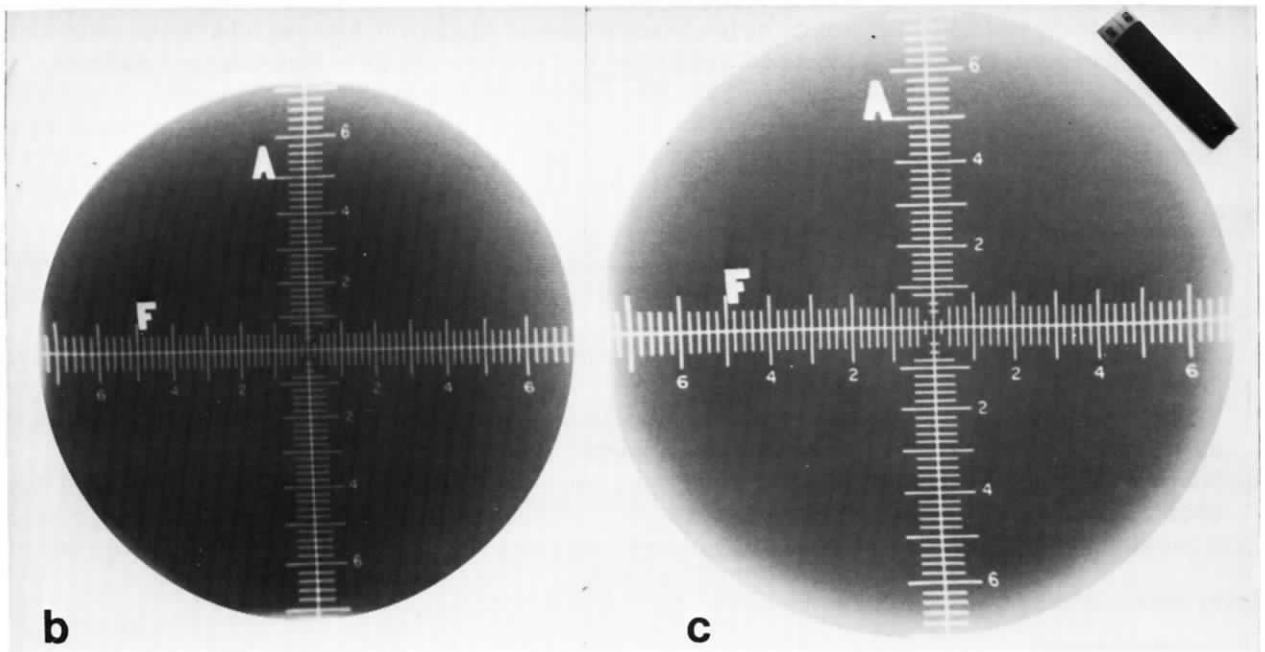


Figure 9.2b and c. Fluoroscopic image size and beam limitation test results. (b) Fluoroscopic image of test template. (c) Spot film image of template.



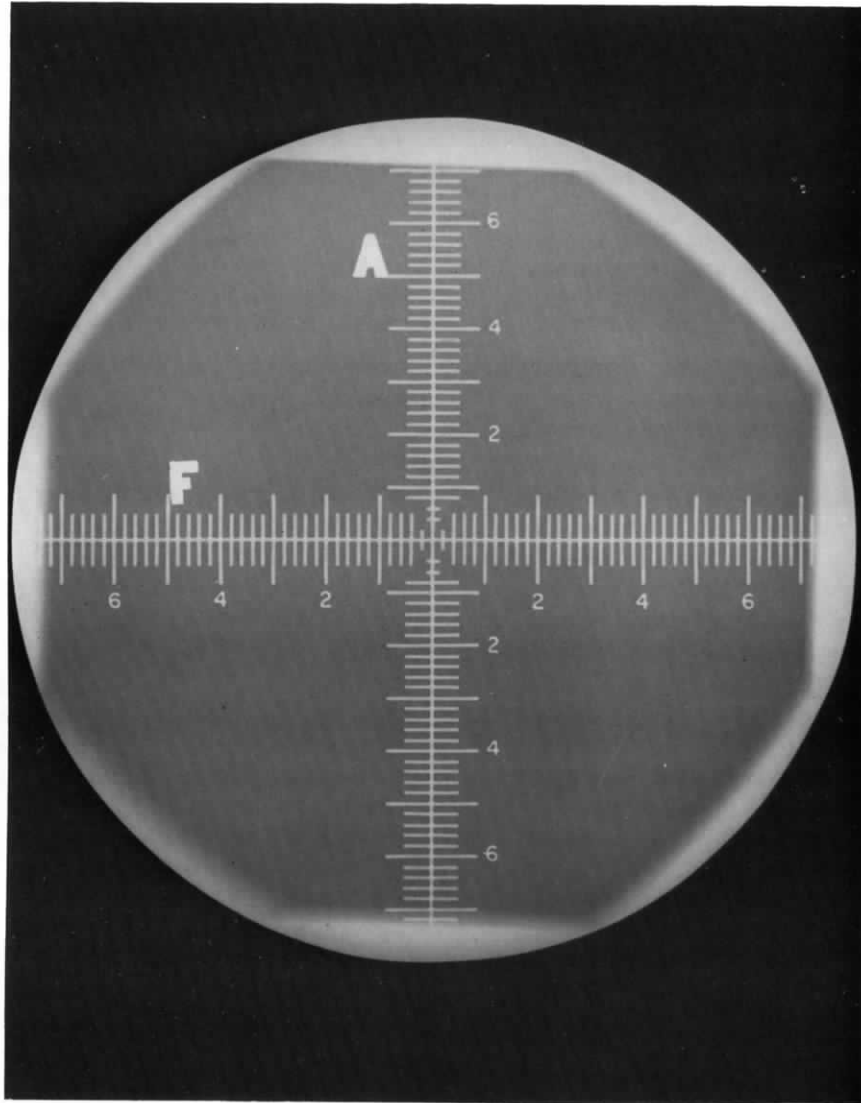


Figure 9.3. Nonscreen x-ray film showing template and collimator leaves location.

4. The total width or length of the x-ray field size should be no greater than 3% of the SID. In multimode systems, the collimation should automatically change to meet the size of the mode selected. In most modern systems, the x-ray field size can easily be kept within 1 cm of the image receptor size.

**Corrective Action**

1. Have a qualified service engineer correct any problems in sizing or beam limitation.
2. Before the service engineer leaves your facility recheck the sizing and beam limitation to be sure it meets the above acceptance limits.
3. One method to eliminate the necessity of the beam limitation test procedure is to have the shutters adjusted so they are just visible on the edge of the image at all times; then a simple visual check is all that is needed.

**9.2. MAXIMUM FLUOROSCOPIC EXPOSURE RATE**

**Purpose**

1. To assure an exposure rate adequate to perform quality fluoroscopic examinations on patients of all sizes.

2. To prevent excessive exposure to patients subjected to fluoroscopic examinations.
3. To assure that you meet Bureau of Radiological Health (BRH) maximum exposure rates.

#### **Equipment Needed**

1. Direct readout dosimeter (preferable)
2. Low-energy pen dosimeter with a range in excess of 1 R and a stopwatch (if direct readout dosimeter is not available)
3. Two 1/8-inch (3-mm) sheets of lead
4. Supports to hold lead above ionization chamber

#### **Procedure—Fluoroscopic Systems with Undertable X-ray Tube, Performed with a Direct Readout Dosimeter**

1. Set the fluoroscopic machine controls on automatic exposure (automatic brightness control) mode.
2. Turn mA and kVp controls to maximum, if controls are available.
3. Place dosimeter chamber on tabletop. [**Note:** Remove any padding if the system is used with and without padding.]
4. Precisely position the dosimeter chamber in the center of the radiation field with fluoroscopy. [**Note:** If all of the active volume of the chamber is not included in the field, the chamber cannot be used for this procedure.]
5. Adjust the fluoroscopic shutters so they are just visible on the edges of the image but do not cover any of the active volume of the chamber (Figure 9.4).
6. Turn the dosimeter to the exposure rate mode.
7. Place the two lead sheets on the supports to prevent damage, above the ionization chamber (Figure 9.5).
8. Fluoroscope long enough for the automatic exposure controls to stabilize, making sure the beam is completely attenuated. You should not be able to see any light areas on the fluoroscopic monitor.
9. Read and record the exposure rate in the QC room log. [**Note:** It may be worthwhile to record the indicated mA and kVp for future reference.]
10. Place the fluoroscopic machine in the manual mode with the mA and kVp controls at the maximum settings.
11. Read and record the exposure rate in the QC room log.

#### **Procedure—Undertable Fluoroscopic Tube and Pen Dosimeter**

Follow previous procedure except for:

1. Position the pen dosimeter in the center of the field (fluoroscopically).
2. Mark the position of the chamber with a piece of wire or a bent paper clip (Figure 9.6).
3. Place the lead sheets on the support and fluoroscope long enough for the automatic brightness controls to stabilize.
4. Charge and zero the dosimeter.
5. Position the dosimeter within the perimeter of the chamber position marker (paper clip).
6. Fluoroscope the pen dosimeter using a stopwatch to time the exposure:
  - a. For a dosimeter with a maximum reading in the 1 to 1.5 R range, fluoroscope for 6 seconds.
  - b. For a 5-R dosimeter, fluoroscope for 20 seconds.
7. Read the pen dosimeter using the reading light on the charger assembly.
8. Repeat Steps 4 through 7 three times and average the readings.
9. Multiply the reading by 10 for a 6-sec exposure or by 3 for a 20-sec exposure to get the exposure rate per minute.
10. Record the results in the QC room log.

#### **Procedure—Overtable Fluoroscopic Systems**

Follow previous procedures except position the chamber 30 cm above the tabletop (Figure 9.7).

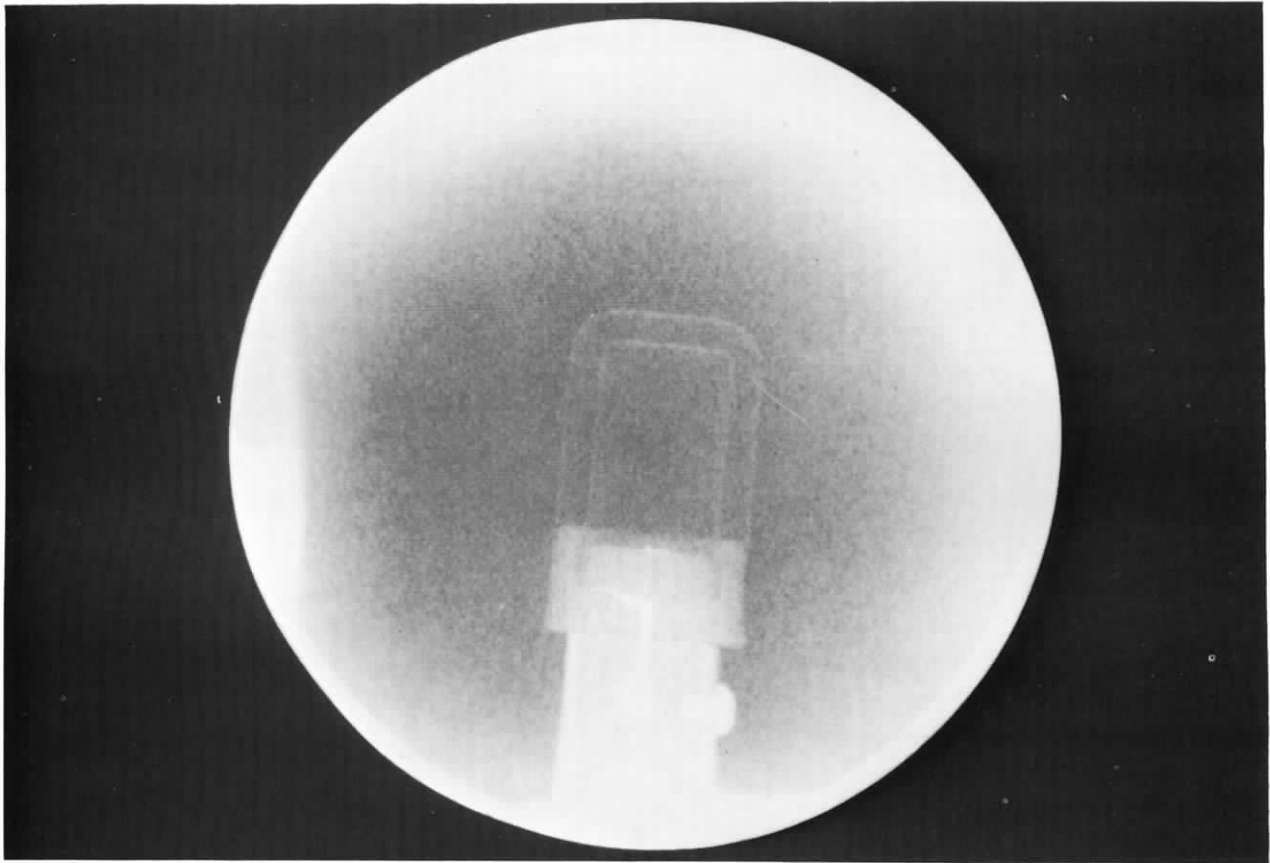


Figure 9.4. Maximum fluoroscopic exposure rate test setup. Fluoroscopic image showing location of ionization chamber in the middle of the x-ray field with collimator leaves visible on all sides.

#### **Procedure—C-arm Systems**

Follow previous procedures except position the chamber 30 cm above the input to the image amplifier (Figure 9.8).

#### **Problems and Pitfalls**

1. Be careful to establish and outline, in writing, your procedure for controlling collimation, chamber position, and all other factors so that you or anyone in your department can *exactly* duplicate the procedure. The description of your procedure should be included in the QC room log.
2. Be extremely careful of the chamber position in systems that have x-ray tubes with anode angles of less than  $12^\circ$ . The heel effect can vary the exposure rate readings by 30% or more.
3. Reading with a pen dosimeter and a stopwatch may have a high degree of error. If the exposure rate is close to the acceptance limits, have your system rechecked with a direct readout dosimeter.
4. Reset the maximum exposure rate *only* with a direct readout dosimeter.

#### **Acceptance Limits**

BRH regulations for equipment certification (acceptance testing) state that the maximum fluoroscopic exposure rate shall not exceed 5 R/min in the manual mode and shall not exceed 10 R/min in the automatic exposure mode.

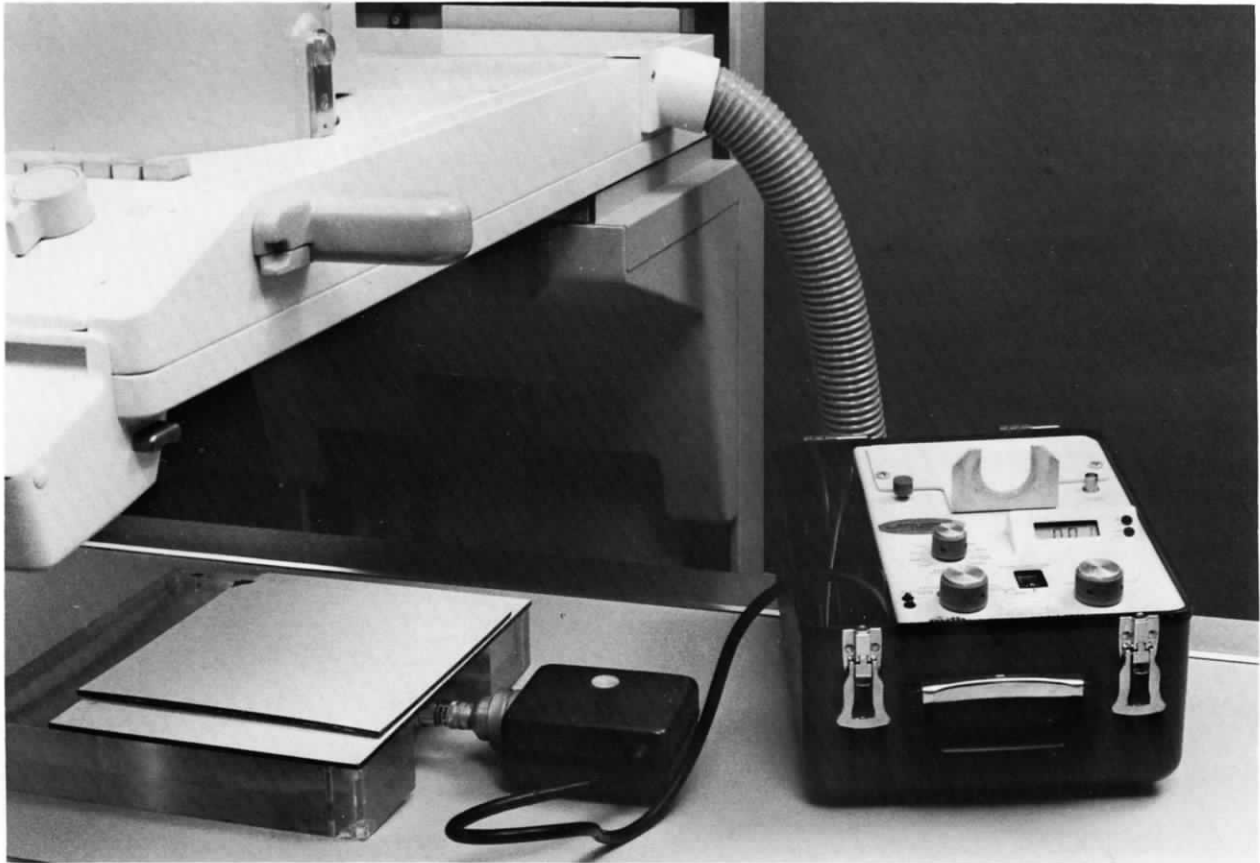


Figure 9.5. Maximum fluoroscopic exposure rate test setup for undertable tubes.

#### **Corrective Action**

If the maximum exposure rates exceed BRH regulations, have a qualified service engineer reset them. Be sure to recheck the maximum exposure rate before the service engineer leaves.

### **9.3. STANDARD FLUOROSCOPIC EXPOSURE LEVELS**

#### **Purpose**

1. To assure long-term consistency of the exposure rate.
2. To establish and maintain the lowest reasonable exposure rate.

#### **Equipment Needed**

1. Direct readout dosimeter (preferable)
2. Low-energy pen dosimeter with a range in excess of 1 R and a stopwatch (if a direct readout dosimeter is not available)
3. A phantom:
  - a. A standard patient equivalent phantom (PEP)
  - b. A smooth-bottomed water bath, at least 10 inch (25 cm) in diameter and with a water depth approximately 0.75 times the patient size you wish to simulate (i.e.,  $21 \text{ cm} \times 0.75 = 15.8 \text{ cm}$  of water depth)
  - c. Two  $7 \times 7 \times \frac{3}{4}$ -inch ( $18 \times 18 \times 2$ -cm) thick pieces of aluminum [**Note:** This phantom is approximately equivalent to a 21-cm thick patient in absorption, but the scatter characteristics may be different since it is much smaller.]
4. A support system to allow room under the phantom for the dosimeter chamber



Figure 9.6. Maximum fluoroscopic exposure rate test setup for undertable tubes with a pen dosimeter. Although pen dosimeters are not recommended, it is possible to use them. It is necessary to locate the center of the field and mark this with paper clips so the dosimeter can be replaced in the exact center without fluoroscopic exposure.

### Procedure

1. Carefully establish and outline, in writing, a repeatable procedure controlling collimation, tower height, operating mA and/or kVp if controls are available, dosimeter, and phantom position, e.g., collimators just visible on the edge of the field, tower 6 inches (15 cm) above the phantom, and the active volume of the chamber in the center of the x-ray field.
2. Place the phantom and the support system on the table with the dosimeter under the phantom and assure that the collimation, tower height, etc. are properly adjusted (Figure 9.9).
3. For the pen dosimeter and stopwatch follow the procedure describing measurement of maximum exposure rate on page 134.
4. Place the dosimeter in the exposure rate mode.
5. With the phantom and dosimeter chamber properly positioned, fluoroscope long enough for the reading to stabilize.
6. Read and record the exposure rate in the QC room log. [**Note:** It may be helpful to record the indicated mA and kVp. These data could be helpful in evaluating the cause of shifts in the standard operating exposure rate in the future.]
7. Make and record readings with and without the grid, and in the 6- and 9-inch (15- and 23-cm) modes for dual mode image amplifiers.
8. For overtable or C-arm systems, be extremely careful to fix and record the source-to-chamber distance.
9. Record the results in the QC room log.

### Problems and Pitfalls

1. A poorly designed or improperly followed procedure will only provide erroneous and confusing data!

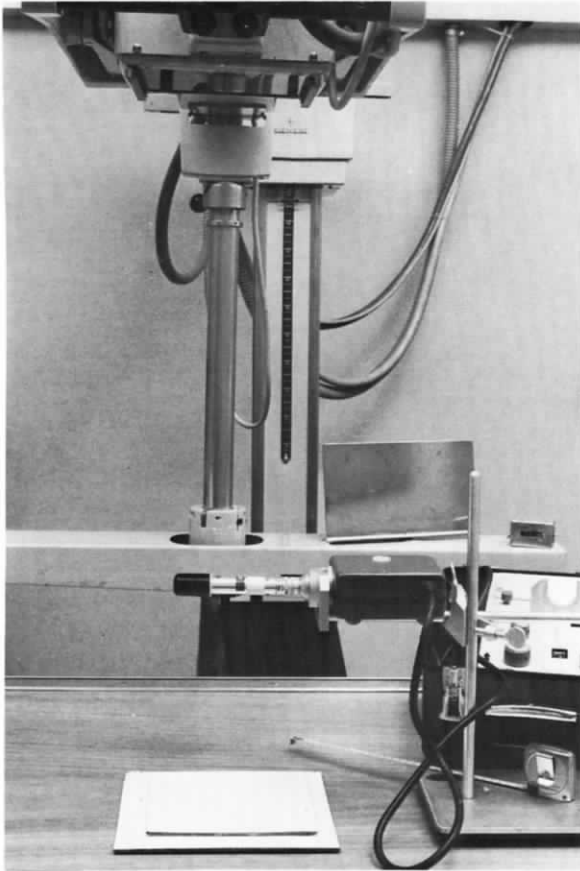


Figure 9.7. Maximum fluoroscopic exposure rate test setup for overtable tubes.

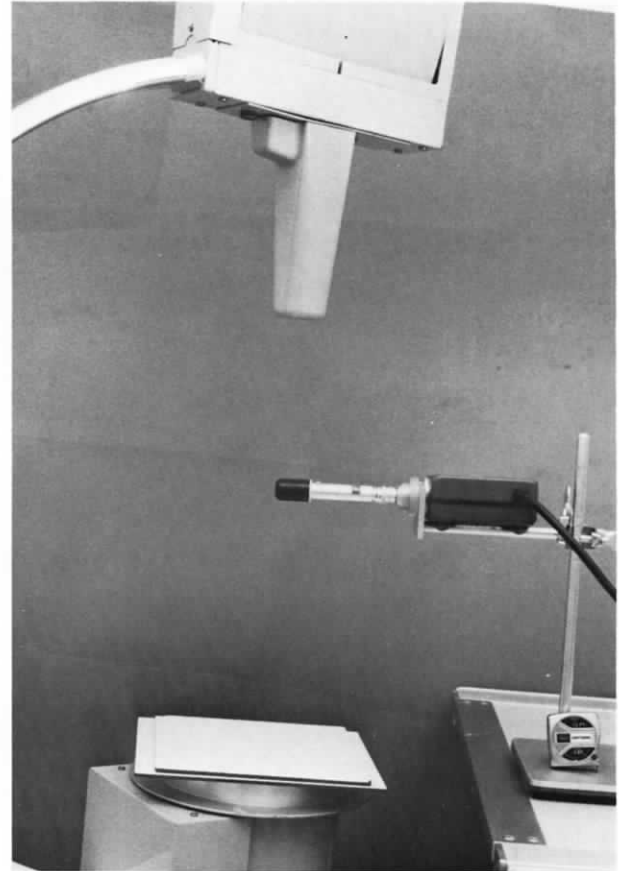


Figure 9.8. Maximum fluoroscopic exposure rate setup for C-arms.

2. Be very careful of the chamber position in systems that have x-ray tubes with an anode angle of less than  $12^\circ$ .

#### Acceptance Limits

The exposure rate needed for each individual machine is affected by many factors such as age, design, kVp range, and filtration, so the values given are only an approximation. A modern fluoroscopic machine operating without a grid through a 20–22-cm patient equivalent phantom with a tower height of approximately 14 inches (35 cm) above the table should have an exposure rate of 2–3 R/min in the 6-inch (15-cm) mode and from 1.5–2.5 R/min in the 9-inch (23-cm) mode. A system operating with a grid will have an exposure rate 1.5 to 2 times higher, depending on grid ratio and interspace material, than the exposures quoted for nongrid.

#### Corrective Action

With the help of a service engineer, adjust the exposure rate to the minimum needed to produce a quality image. [Note: See pages 190–192 on ways to reduce fluoroscopic exposure rates.]

#### 9.4. AUTOMATIC BRIGHTNESS CONTROL (ABC), AUTOMATIC DOSE CONTROL (ADC), AND AUTOMATIC GAIN CONTROL (AGC)

##### Purpose

To assure that the automatic exposure and video gain controls are functioning properly. [Note: Not all fluoroscopic systems have the same combinations of exposure and gain control.]

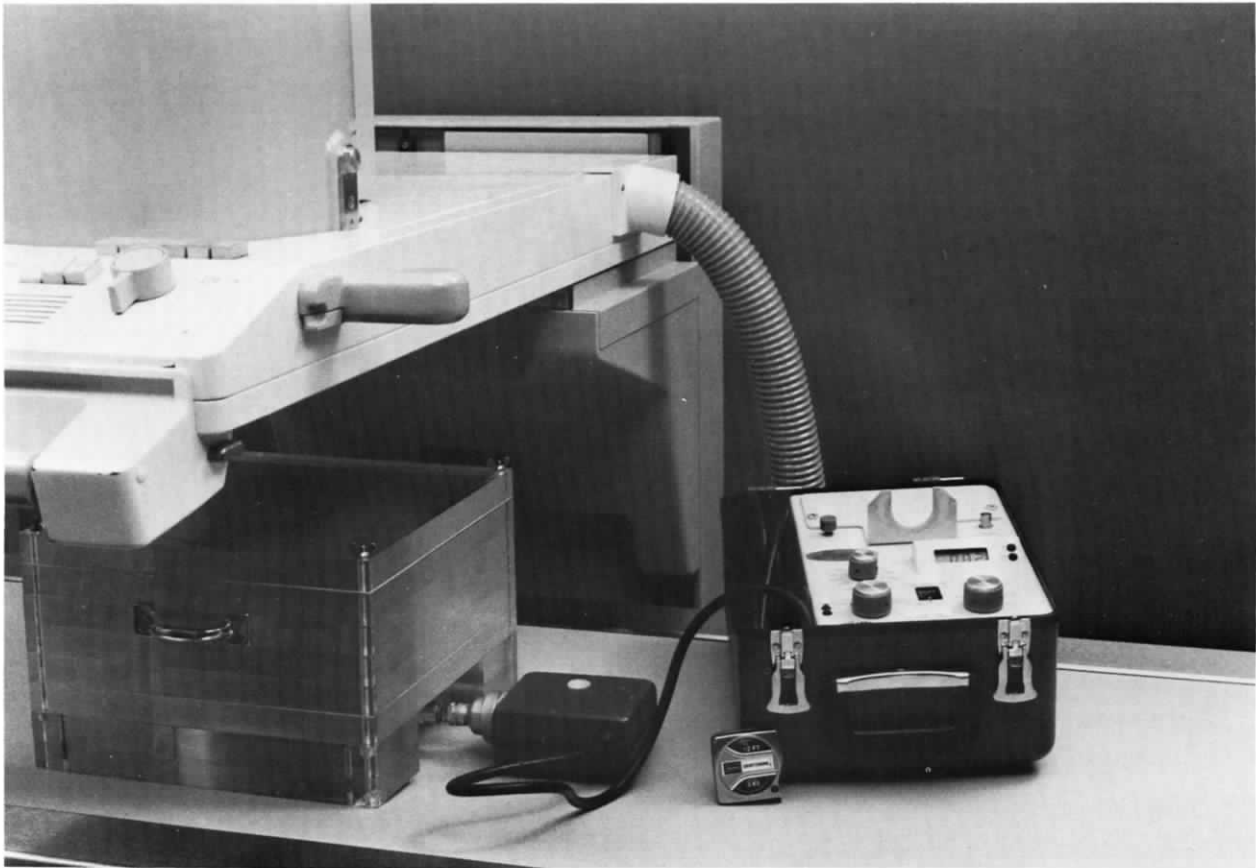


Figure 9.9a. Standard fluoroscopic exposure level test setup with direct readout dosimeter (preferred).

### Equipment Needed

1. Patient equivalent phantom (PEP)
2. Direct readout dosimeter (preferable)
3. Low-energy pen dosimeter with a range in excess of 1 R and a stopwatch (if direct readout dosimeter is not available)
4. Support system to hold phantom above dosimeter
5. Aluminum sheets used to measure the half-value layer

### Procedure—ABC and ADC Controls

1. Set up the phantom and dosimeter following the same procedure you established to measure the standard fluoroscopic exposure rate, carefully controlling the field size, tower height, and chamber position. Be sure the controls are set in the automatic mode.
2. Fluoroscope long enough for the automatic exposure system to stabilize, then read and record the exposure rate for the full phantom (for the pen dosimeter follow the procedure described on page 134 in the description of measuring maximum fluoroscopic exposure rate).
3. Remove half the phantom [three 1-inch (2.5-cm) Lucite blocks or one ¾-inch (2-cm) aluminum block].
4. Read and record the exposure rate for the half phantom in the QC room log.

### Problems and Pitfalls

1. Only well-designed and easily reproduced procedures will provide useful information.

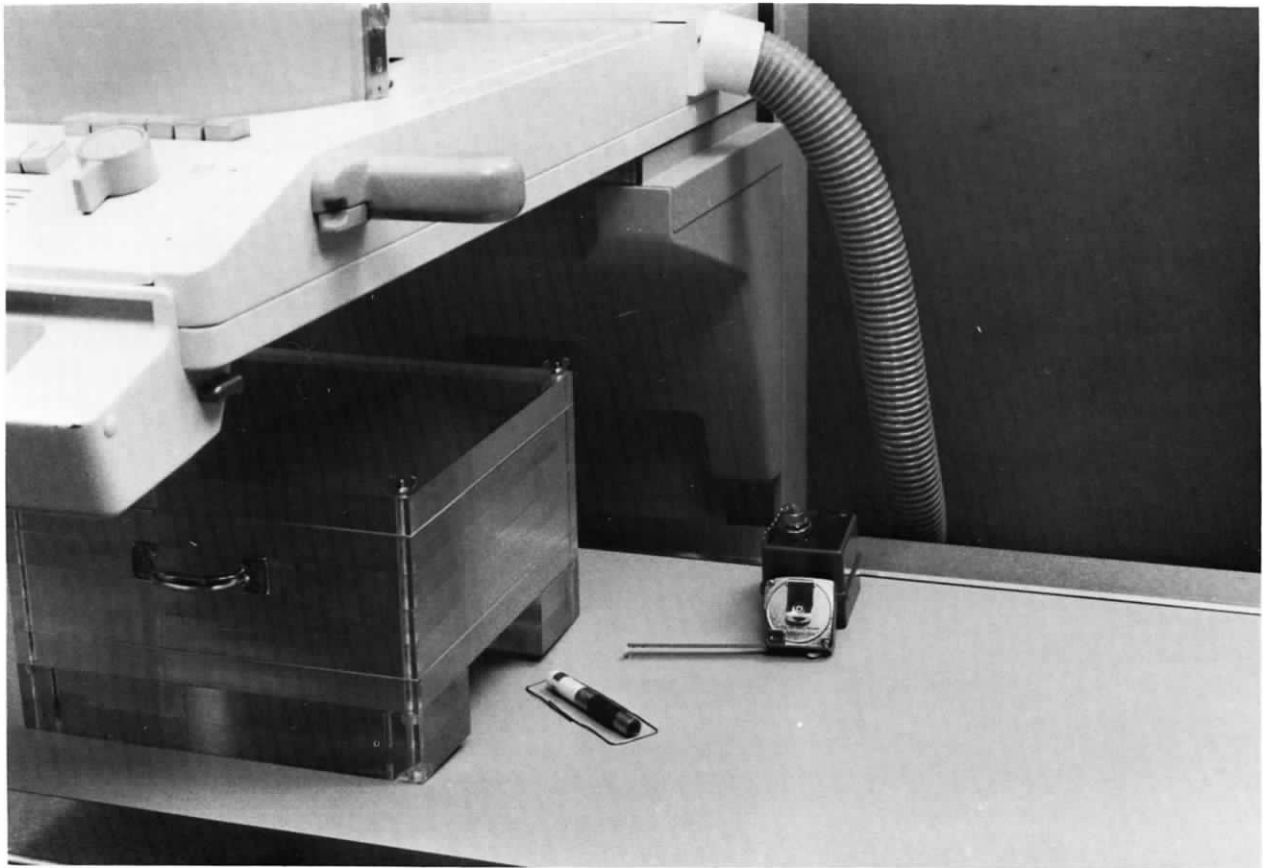


Figure 9.9b. Standard fluoroscopic exposure level test setup with pen dosimeter (not recommended).

2. There are several different styles of automatic exposure control systems. Some vary only the kVp, some vary only the mA, and some change the mA and kVp. Take the time to learn the function of the automatic exposure control system before making any judgment about the condition of your equipment.
3. Do not attempt to compare the results of different models of automatic exposure control systems.

#### Acceptance Limits

1. Because of the many different types of automatic exposure control systems, and exponential absorption of the x-ray beam, no specific values can be given, but the exposure rate for the half phantom should be approximately  $\frac{1}{2}$  the values for the full phantom.
2. The ideal situation would be to perform this test just after the equipment was installed or after a service engineer has verified the condition of the automatic exposure control system. Follow-up checks should then produce similar results.

#### Corrective Action

If the automatic exposure control system fails, or if you question the function, consult a qualified service engineer.

#### Procedure—Automatic Gain Control (AGC) Functional Verification

An AGC system is incorporated in some, but not all, fluoroscopic equipment to provide a consistent brightness on the TV monitor. The AGC control varies the amplification of the video signal coming from the TV camera, and usually varies the video amplification along with but independently of automatic exposure control for changes in body part thickness. An additional benefit of an AGC system is that it broadens the useful range of a fluoroscopic unit beyond the limits of the automatic exposure control.

1. Place the phantom, phantom support, and dosimeter on the table following the same procedure established to measure the standard fluoroscopic exposure rate.



2. Remove three of the six blocks if the Lucite phantom is used; if the aluminum phantom is used leave both  $\frac{3}{4}$ -inch (2-cm) thick blocks in place.
3. *Manually* match the mA, kVp, and exposure rate with the factors used by the automatic exposure control system.
4. Observe the image and mentally note the brightness and quality using the appearance of the dosimeter chamber as part of the impression.
5. Add one 1-inch (2.5-cm) thick Plexiglas block, or 2 mm of aluminum if the aluminum phantom is being used.
6. Observe the image brightness and quality. [**Note:** The image noise will increase because you are increasing the quantum mottle and electronic noise by increasing the video amplification.]
7. If the brightness did not change, add an additional 1 inch (2.5 cm) of Lucite or 2 mm of aluminum and observe image brightness and quality. Continue this procedure until the brightness of the TV image dims. If you have used all six of the Lucite blocks or 6 to 8 mm of aluminum and the image brightness has not changed, stop the procedure and assume the AGC system functions very well.
8. Record the mA, kVp, and dose rate used for the procedure, plus the amount of Lucite or aluminum needed to change the image brightness in the QC room log.

#### **Problems and Pitfalls**

1. Be very careful when setting the manual controls. If the mA, kVp, and exposure rate are not correctly set, you may have the AGC at minimum or maximum limits before you start the procedure, which will give you a false impression of the condition of the AGC system.
2. Before you make any judgment about the function of the AGC system, you must thoroughly understand how your system was designed to perform. Consult a service engineer who is familiar with your type of equipment for information about the function of the AGC system in your equipment.
3. This procedure is not a quantitative test, but rather a means of assuring that your AGC system is functioning.

#### **Acceptance Limits**

1. Expect the AGC system to function similarly on periodic checks.
2. Expect AGC systems from the same manufacturer and of the same design to perform similarly.

#### **Corrective Action**

If you feel the AGC is not functioning properly, consult a service engineer.

### **9.5. TV MONITORS AND VIDEOTAPE AND VIDEODISC RECORDERS**

#### **Purpose**

To assure that the image display and recording systems are functioning properly.

#### **Equipment Needed**

1. Copper mesh resolution test target, or lead resolution target
2. Step wedge
3. Coarse mesh such as a screen contact test mesh
4. Video signal generator (ideal, but not commonly available)

#### **Procedure—TV Monitors**

Video signal generators with gray scale, resolution, and distortion patterns are the best method of checking TV monitors, but they are expensive and complex. Some simple checks include:

1. Observe the TV scan lines for sharpness from the center to the edge of the monitor.
2. Check the positions of the brightness and contrast knobs. If the settings are at one extreme or the other to produce the correct brightness and contrast, this could be an indication of weak components or an incorrect video signal entering the monitor. For most systems, a composite video signal including video and sync pulses should be between 0.9 and 1.2 volts.
3. To check for distortion, place a piece of coarse mesh flat on the table. Fluoroscope and observe the mesh pattern from center to edge. The mesh pattern will appear stretched at the edges of the image, but it should be distorted equally on all edges of the image (Figure 9.10).

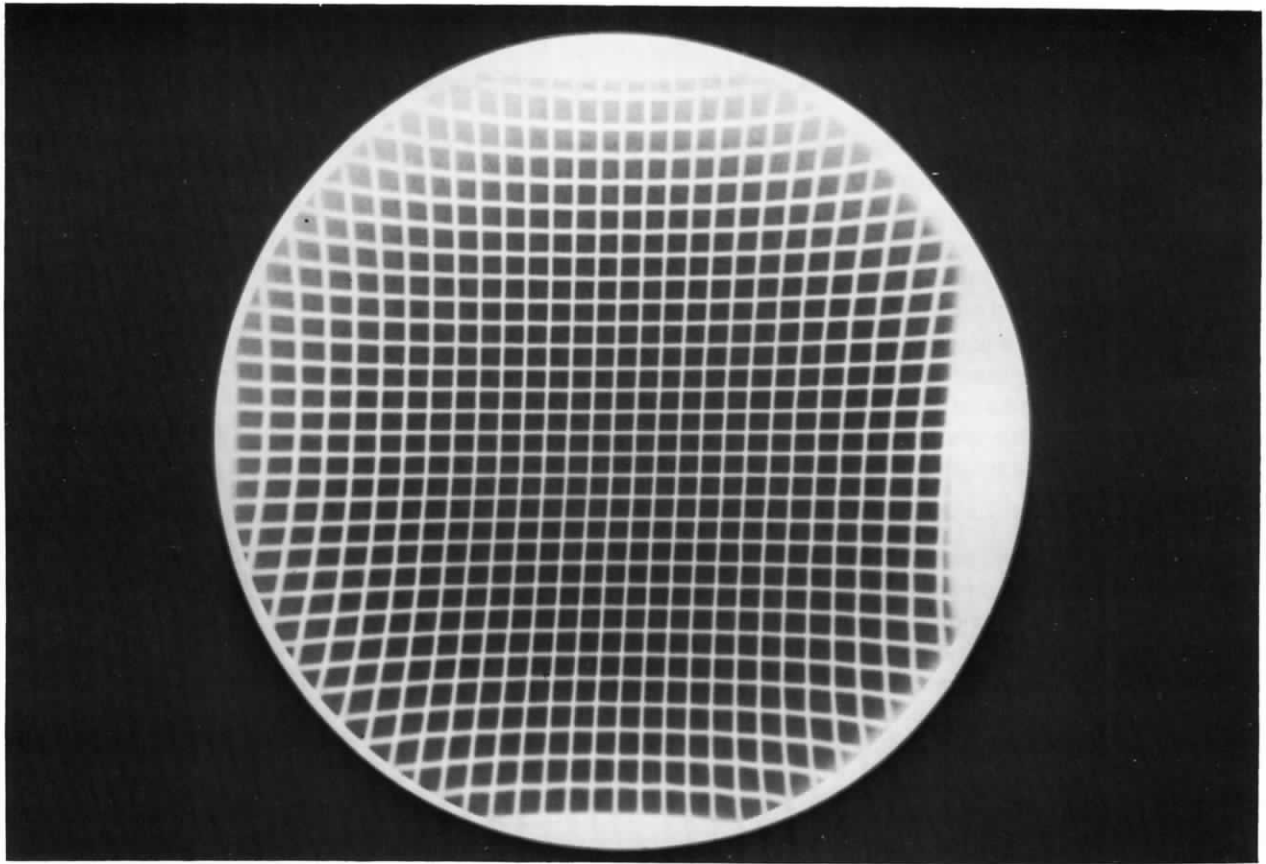


Figure 9.10. TV monitors and videotape and videodisc recorder test results. Fluoroscopic image of coarse mesh (from screen-film contact test) showing the amount of distortion that may be anticipated in conventional fluoroscopic imaging systems.

4. Record the results in the QC room log.

#### **Problems and Pitfalls**

Monitors are an important link in a fluoroscopic system, yet it is very difficult to separate out the monitor from the other components of the system. The checks described may only provide an indication of problems. If you are suspicious of a problem, have a service engineer thoroughly check your monitor and the video signal entering the monitor.

#### **Acceptance Limits**

A judgment must be made by a qualified service engineer.

#### **Procedure—Video Recording Systems**

1. Fluoroscope the copper mesh or the lead resolution target and record the finest mesh or bar pattern visualized on the monitor. [**Note:** The copper mesh should be oriented at  $45^\circ$  to the TV scan lines and the lead test target should be at  $90^\circ$  to the scan lines.]
2. Replay the recorded image and record the finest mesh or bar pattern resolved (Figure 9.11).
3. Repeat the procedure with a step wedge and note any changes in contrast.
4. Record the results in the QC room log.

#### **Acceptance Limits**

1. For a high-quality videodisc recorder with a maximum response in the 4 MHz range, expect to lose 0.5 to 0.7 cycle/mm if a lead resolution target is used, or 1 mesh size if a copper mesh test tool is used.
2. For a videotape unit with approximately a 3 MHz response, expect to lose 0.8 to 1 cycle/mm on a lead resolution target and 2 mesh sizes for a copper mesh resolution test tool.

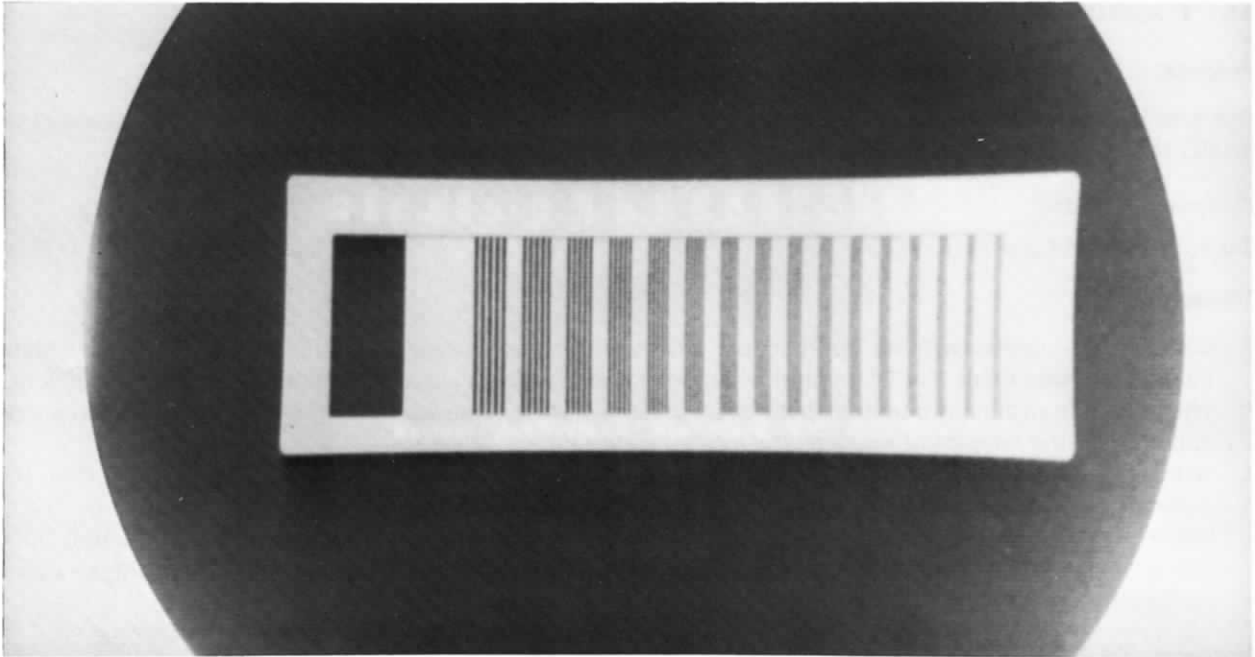


Figure 9.11a. Videotape recorder test results (real-time fluoroscopic image). A lead resolution pattern was imaged fluoroscopically and then tape-recorded so the effects of tape recorder degradation could be noted.

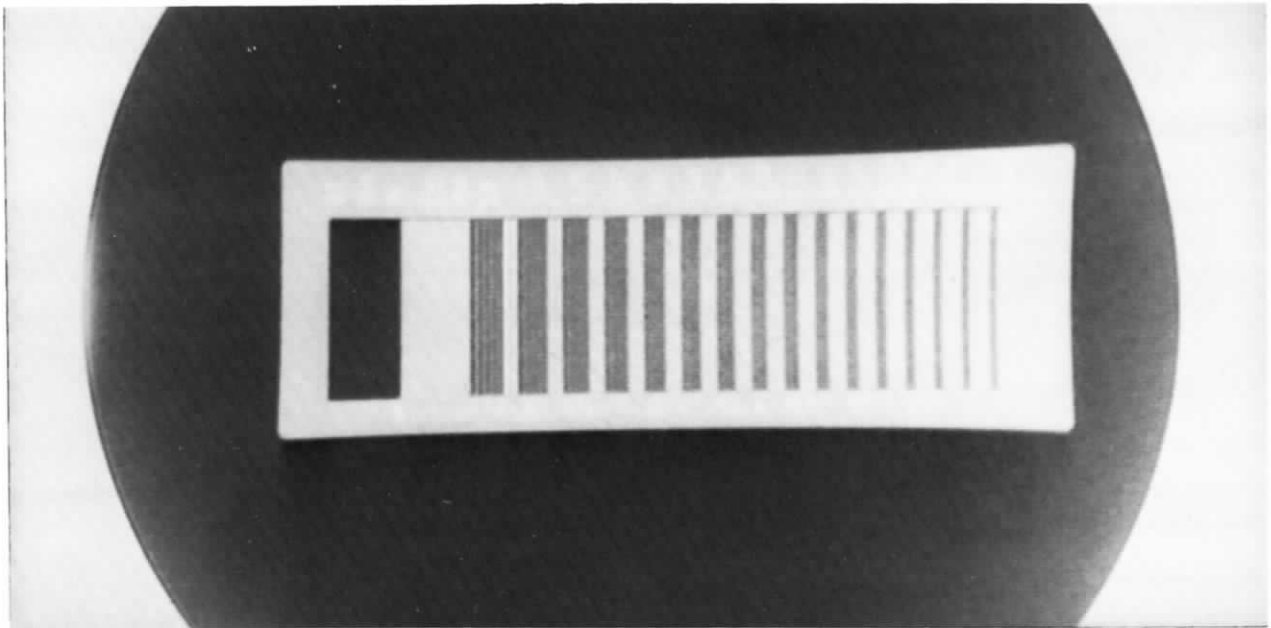


Figure 9.11b. Image replayed from videotape recorder. Note the significant loss in resolution and sharpness.

3. Little or no change in contrast should be seen between the live and the stored image.

#### **Corrective Action**

1. Follow maintenance schedule for head cleaning.
2. If excessive resolution is lost or the contrast changes greatly, consult a service engineer.
3. If noise is excessive, try cleaning the recording and playback heads. If this does not help, consult a service engineer.

## 9.6. FLUOROSCOPIC IMAGE NOISE

### Purpose

This test is only intended to help isolate the cause of troublesome image noise in televised fluoroscopy that results from either quantum mottle or electronic noise.

### Equipment Needed

Patient equivalent phantom (PEP)

### Procedure

1. Observe the monitor with no fluoroscopic image. Any noise will be electronic in nature. [**Note:** Many modern systems blank the TV monitor when no signal is present, which voids this part of the procedure.]
2. With the uniform density phantom in the beam and the system in the automatic exposure mode, fluoroscope and observe the amount of noise on the image (Figure 9.12).
3. With the system in the manual mode, match the fluoroscopic mA and kVp with the factors from the automatic mode.
4. While observing the fluoroscopic image noise, gradually increase the mA until the image is saturated. If the amount of noise decreases with the increased exposure rate (increased mA), the noise is probably quantum mottle. If the amount of noise does not change, it is probably electronic noise.

### Problems and Pitfalls

There are many factors that can influence the amount of noise on an image. This test may well be influenced by any of these factors and confuse the test results.

### Acceptance Limits

If the noise is so severe that it is affecting the ability of your radiologists to make a diagnosis, corrective action must be taken.

### Corrective Action

1. Have a qualified service engineer evaluate your system.
2. If the problem is electronic in nature, the aperture in front of the TV tube should be opened, and the gain of the video amplifier reduced.
3. If the problem is quantum mottle, the exposure rate should be increased until the noise reaches an acceptable level.

## 9.7. IMAGE LAG

### Purpose

To evaluate the lag, smearing, comet tailing, or persistence of video systems used for televised fluoroscopy. This phenomenon appears as a blur of objects in motion in the fluoroscopic image.

### Equipment Needed

1. Patient equivalent phantom (PEP)
2. A fender washer, which is usually 2 inches (5 cm) in diameter with a ¼-inch (6-mm) hole in the center [**Note:** A similar-sized device made of lead will provide the same results.]

### Procedure

1. Place the uniform density phantom on the table with the fender washer in the center of the phantom (Figure 9.13).
2. Fluoroscope the phantom, while moving the tower or tabletop smoothly in a circular pattern around the center of phantom.

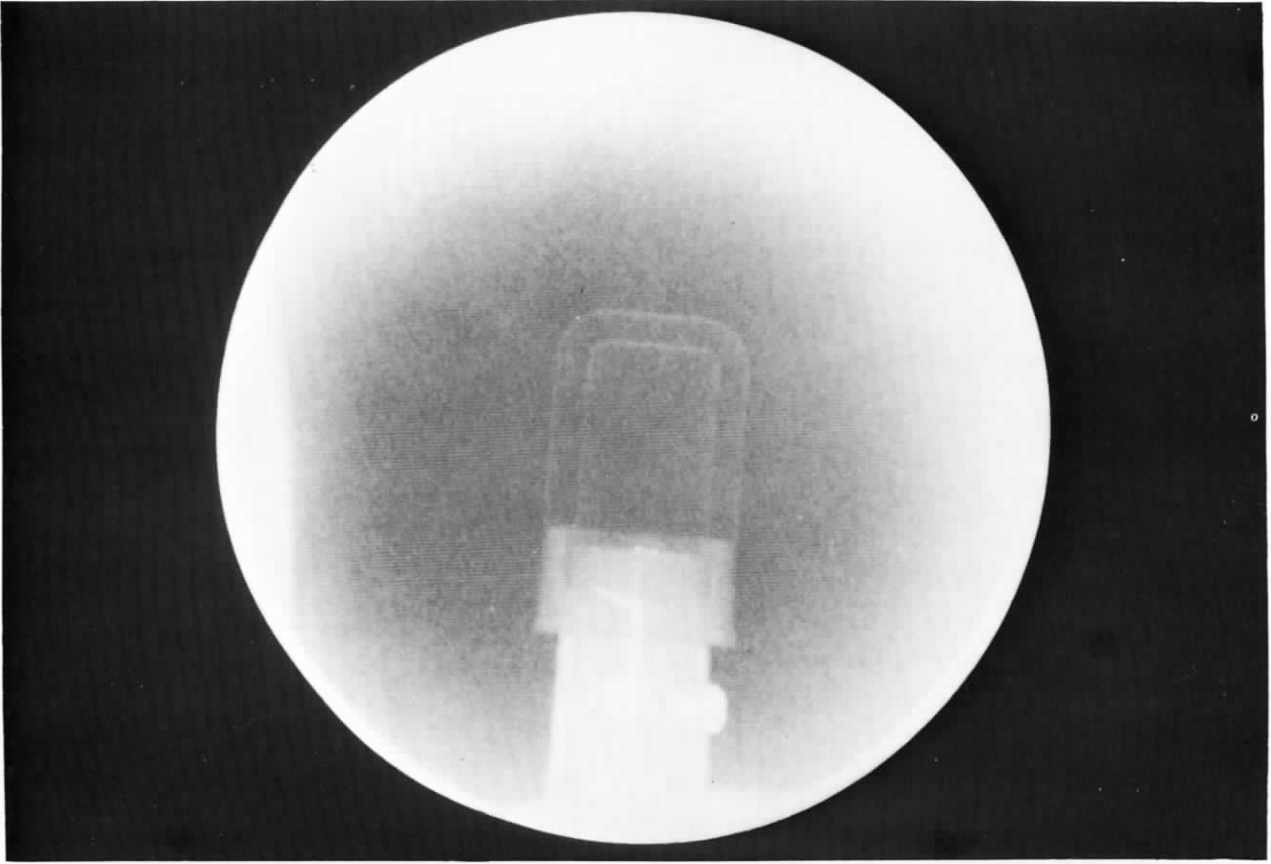


Figure 9.12a. Real-time fluoroscopic image noise at an 8-R/min dose rate.

3. While the tower or tabletop is in motion, note the comet-like tail originating from the hole in the washer and streaking onto the opaque portion of the washer (Figure 9.14).
4. Record your impression of the image in the QC room log.

#### **Problems and Pitfalls**

1. This test only results in a subjective impression on the part of the observer, with absolutely no hard data that can be documented.
2. The only way an observer can develop a feel for this problem is by observing several good and bad systems.
3. The use of an object that is too large, which will cause an increase in exposure by the automatic brightness system, may influence the results of the test.
4. Most vidicon camera tubes, by design, have more lag than plumbicon tubes. Before making any judgment about the condition of your system, find out which type of camera tube you are using.

#### **Acceptance Limits**

A system that exhibits excessive lag and consequently blurs a moving object is in need of repair or readjustment.

#### **Corrective Action**

1. Have your system evaluated by a qualified service engineer.
2. Some lag problems can be resolved by increasing the amount of light reaching the camera tube. This can be accomplished either by opening the aperture in front of the camera tube or by increasing the exposure rate.
3. Replace the camera tube.

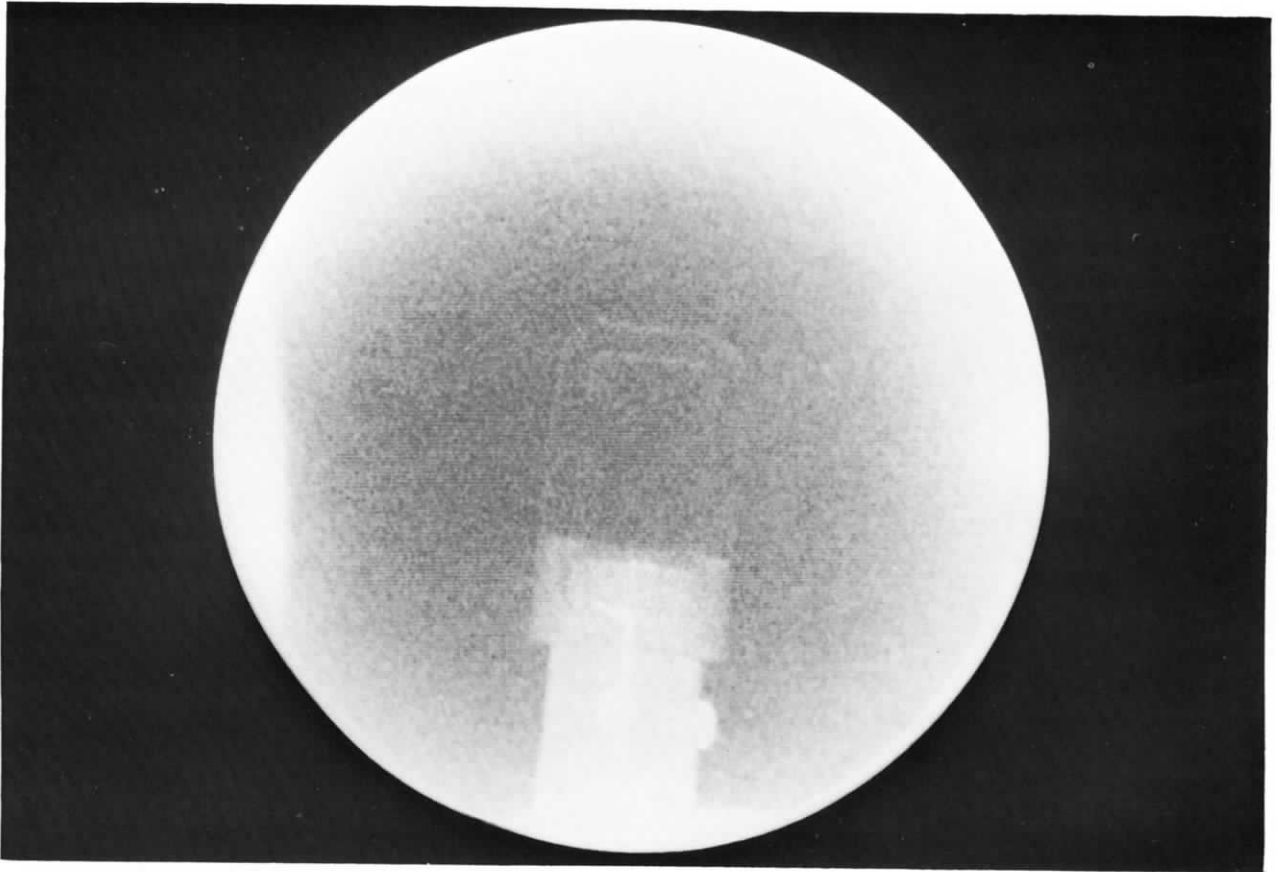


Figure 9.12b. Real-time fluoroscopic image noise at a 3-R/min dose rate.

## 9.8. SETTING AND MAINTAINING CINE AND PHOTOFLUOROSPOT (PFS) FILM CAMERA EXPOSURES

### Purpose

To establish and then assure the correct exposure rate for camera systems that record images from image intensifier tubes.

### Equipment Needed

1. Direct readout dosimeter
2. Patient equivalent phantom (PEP)
3. Test stand or other device to hold the dosimeter in contact with the image intensifier

### Procedure—Photofluorospot (PFS) Film Cameras

1. Set the system to the automatic exposure control mode, and in most cases, to 80 kVp. **[Note:** Check the manufacturer's recommendation in the equipment manuals.]
2. Remove the grid from in front of the image intensifier. **[Note:** On some types of systems the grid is not easily removed. In the case of some equipment a correction factor and instructions to correct for grid attenuation are found in the equipment manuals.]
3. Raise the fluoroscopic tower to its maximum height.
4. Place the PEP on the tabletop.
5. With the dosimeter chamber supported by the test stand, and centered over the PEP, position the chamber as close as possible to the input of the image intensifier (Figure 9.15). **[Note:** Systems with conventional

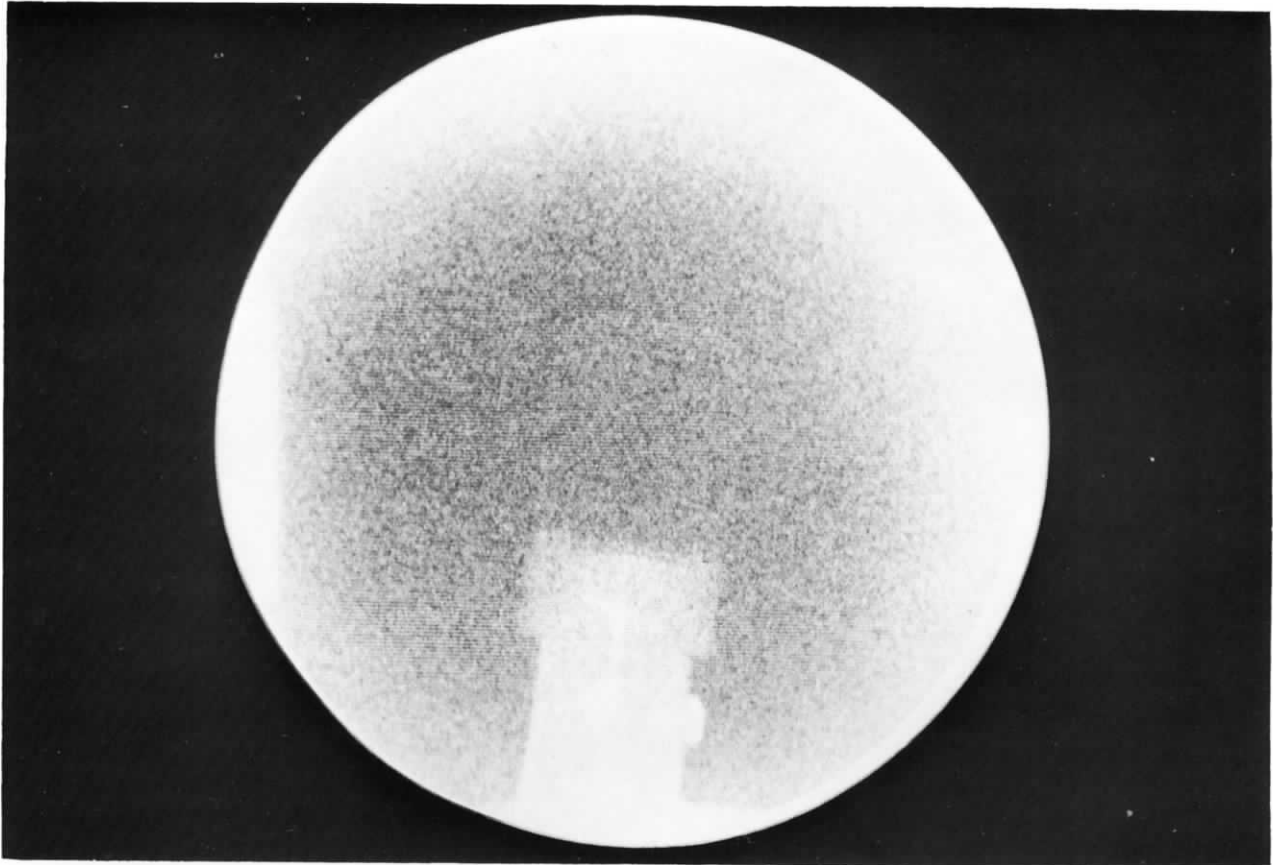


Figure 9.12c. Real-time fluoroscopic image noise at a 0.75-R/min dose rate.

spot film devices will prevent contact with the image tube, but, in most cases, the distance difference will only amount to a slightly lower exposure reaching the image tube.]

6. Fluoroscopically center the chamber to the center of the image intensifier.
7. With the dosimeter in the exposure mode, make, record, and average the exposure for three separate exposures.
8. The typical exposure range, dependent on the image intensifier size and film quality requirements, is from  $50 \mu\text{R}/\text{frame}$  (0.05 mR) to  $200 \mu\text{R}/\text{frame}$  (0.2 mR). Systems that are used for angiography may need exposures in excess of the quoted figures to produce lower-noise films. [**Note:** Check the manufacturer's recommended exposures for your equipment.]
9. With the assistance of a qualified service engineer, adjust the exposure to the desired level, then adjust the aperture in front of the spot film camera to produce the proper film density (typically 0.80–1.20).
10. Confirm the image intensifier entrance exposure and enter it, along with a careful outline of your setup and procedure, in the QC room log.
11. Check and record the entrance exposure to the phantom.
12. On follow-up visits check the entrance exposure to the image tube and the phantom.

#### Procedure—Cine Systems

1. Follow Steps 1 and 3–6 from the procedure for photofluorospot cameras.
2. Removal of the grid on most dedicated cine systems will expose the glass input of the image tube. Because there is some danger if this glass is broken, this procedure should be performed with the assistance of a qualified service engineer.
3. Set your dosimeter to the exposure rate mode.
4. Once the setup is complete, operate your system *without film* at your normal frame rate.

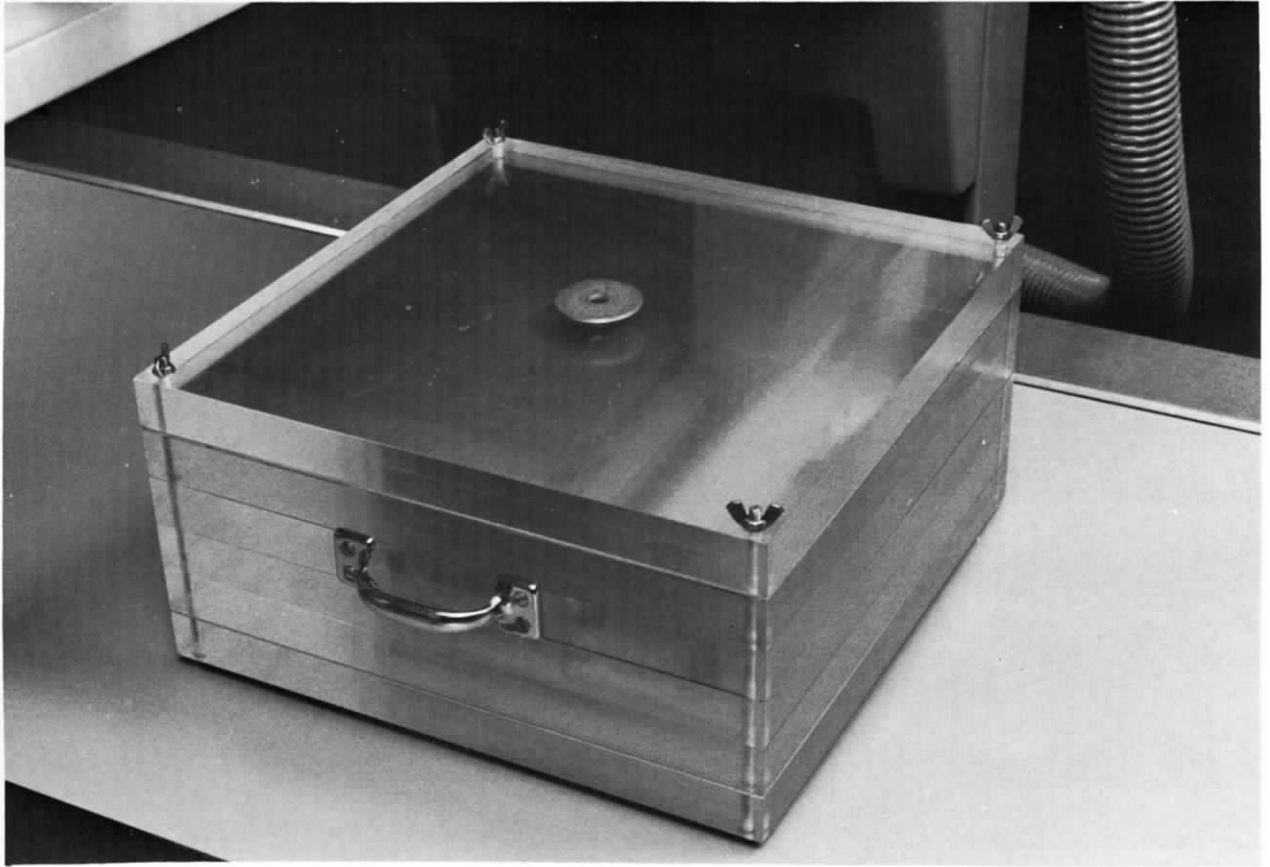


Figure 9.13. Image lag test setup.

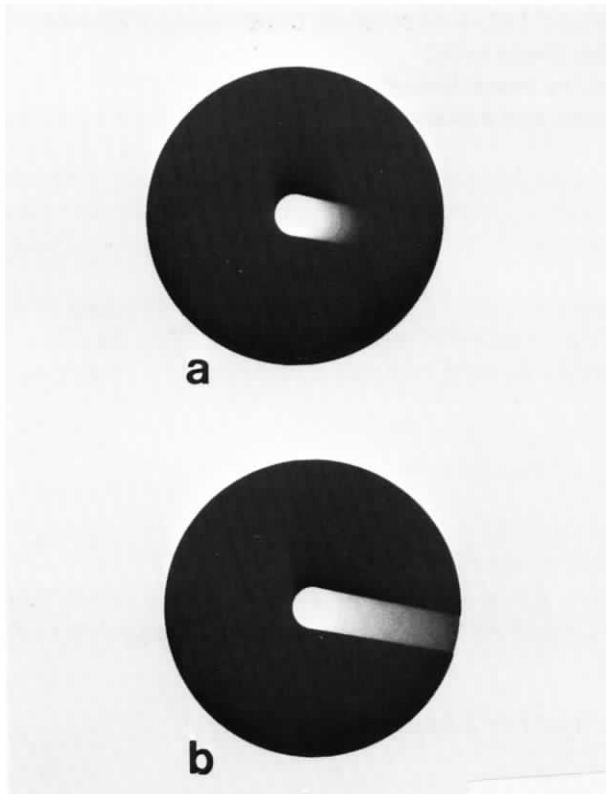


Figure 9.14. Image lag test results. Sketch of fluoroscopic image of fender washer: (a) minimum lag; (b) objectionable lag. [Note: The appearance of the image depends on many parameters in addition to the fluoroscopic system lag, such as dose rate and speed of moving the tower. Consequently, this is *not* a quantitative test, but a test requiring a visual impression.]



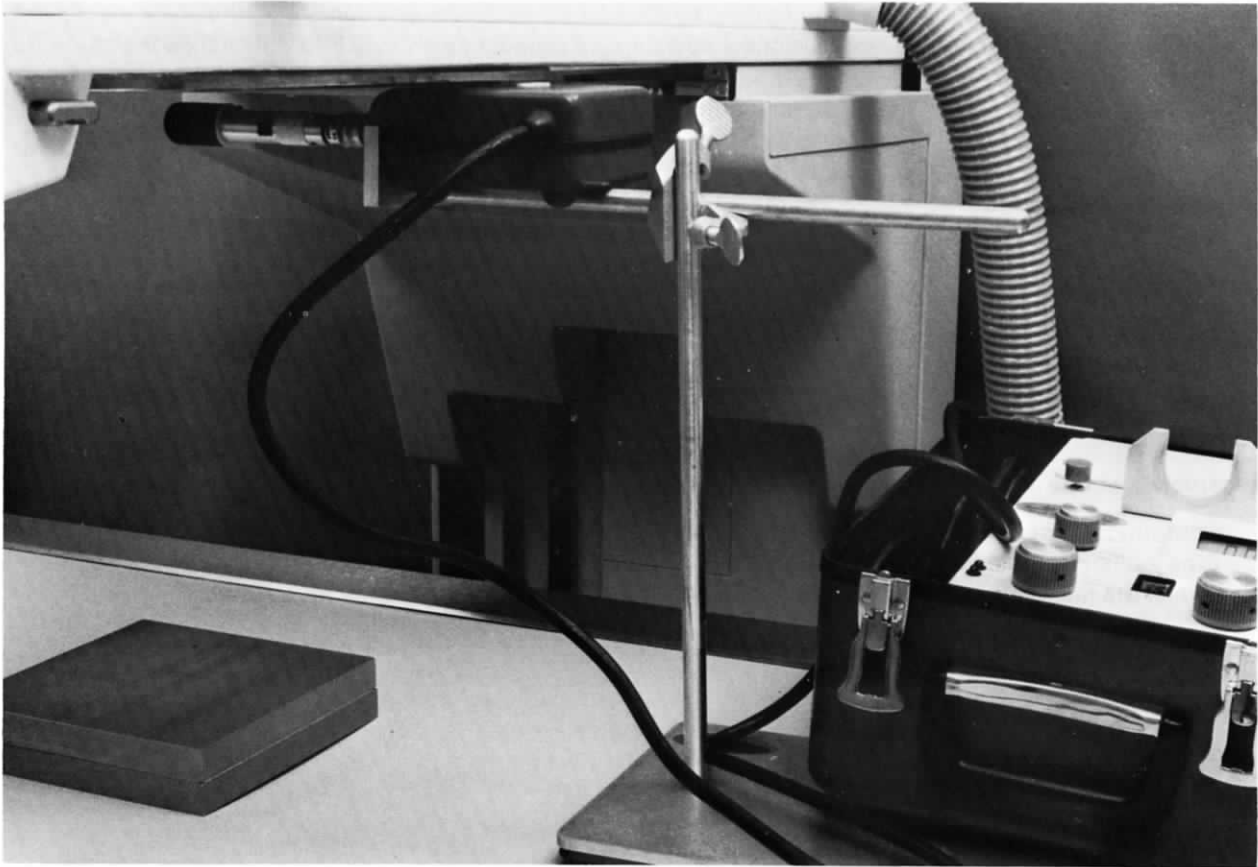


Figure 9.15. Setup for determining the entrance exposure rate at the image intensifier.

5. Run your system long enough for the automatic exposure controls to stabilize, then record the exposure rate (mR/min).
6. To calculate the exposure per frame, divide the exposure per minute by 60 to establish the exposure per second, then divide the exposure per second by the frame rate to determine the exposure per frame. For example, for an exposure rate of 72 mR/min with a frame rate of 60 frames per second (fps):

$$72 \text{ mR/min} \div 60 = 1.2 \text{ mR/sec}$$

$$1.2 \text{ mR/sec} \div 60 \text{ fps} = 0.02 \text{ mR (20 } \mu\text{R) per frame}$$

7. As with most measurements there is some backscatter reaching the dosimeter chamber from the glass and input phosphor of the image tube. Because this procedure is fairly critical, this backscatter must be taken into consideration. In most of the measurements of this type the backscatter amounts to approximately 10–15% of the exposure rate. You can simply subtract 10% of the exposure rate to correct for the backscatter, or attempt to move the image tube away from the chamber to minimize the amount of scatter reaching the chamber. If your automatic exposure system can be locked, run the system unlocked until it has stabilized, then lock it. Once locked in, raise the image intensifier from the chamber and make your measurements. A percentage calculation can be made at this point for future reference by using the measurements with and without backscatter.
8. If you find the entrance exposure rate doesn't meet your needs, adjust the exposure rate, with the assistance of a qualified service engineer, and enter the data in the QC room log.
9. Without moving the dosimeter chamber replace the grid, bring the image intensifier and grid back into contact with the chamber, and then make a measurement of the entrance exposure to the grid. With this data, you can establish a correction factor for the grid that will allow you to check the exposure rate in the future without removing the grid. The correction factor is determined by dividing the entrance rate without the grid by the entrance rate with the grid (e.g.,  $72 \text{ mR/min} \div 90 \text{ mR/min} = 0.80$ ). Future measurements can be

made with the grid in place and, multiplying by the correction factor, you can obtain the entrance rate into the image tube. This value should be checked periodically because drifts in kVp will change the correction factor.

10. If the exposure rate is changed, an adjustment of the aperture of the cine camera may be needed to bring the film density to the desired level (typically 0.80 to 1.20).
11. Measure and record the entrance exposure to the phantom.
12. Carefully outline your setup procedure and calculations, and record these data in the QC room log so this procedure can be duplicated on future visits.

### **Problems and Pitfalls**

If you do not place enough attenuator in the beam, or cannot lower the mA sufficiently, problems may occur with the minimum response time of the phototiming system. For most modern photofluorospot systems, slightly more than 10 msec will be sufficient. In cine systems try to use a pulse width of 2 msec or more to prevent problems.

### **Acceptance Limits**

1. Photofluorospot film cameras: 50 to 200  $\mu\text{R}/\text{frame}$ , or higher for special procedure applications.
2. Cine systems: 9-inch (23-cm) mode, 10–25  $\mu\text{R}/\text{frame}$ ; 6-inch (15-cm) mode, 20–50  $\mu\text{R}/\text{frame}$ .
3. Check the manufacturer's recommendations for both cine and photofluorospot systems.

### **Corrective Action**

1. If you find the exposure or exposure rate outside of the recommended range, adjust the exposure to the appropriate level with the assistance of a qualified service engineer.
2. Whenever possible, try to lower the exposure levels to the minimum that meet the imaging requirements of your system.

## **9.9. FLUOROSCOPIC, PHOTOFLUOROSPOT (PFS) FILM, AND CINE RESOLUTION**

### **Purpose**

To check the resolution capability of the imaging system

1. As seen on the television monitor
2. As recorded on photofluorospot film
3. As recorded on cine film

### **Equipment Needed**

1. Copper mesh test target composed of eight pie-shaped segments of 16, 20, 24, 30, 35, 40, 50, and 60 mesh per inch
2. Patient equivalent phantom (PEP)

### **Procedure—Fluoroscopic Systems with Mirror Optics or Television Viewing**

1. Center and tape the test target to the face plate of the image intensifier (Figure 9.16).
2. Collimate the beam and adjust the fluoroscopic factors.
  - a. For manual brightness systems collimate the beam to the test target (Figure 9.17a) and adjust the fluoroscopic factors to best visualize the test target, e.g., about 50 kVp and 1 mA.
  - b. For automatic brightness systems collimate to the test target. The system should automatically adjust to visualize the test target, but systems with minimum or fixed kVp should be set to approximately 50 kVp. Half of the PEP may be used to attenuate the beam if whiteout occurs because of the system's inability to adjust to extremely low radiation levels.
3. On television systems adjust the contrast and brightness controls on the TV monitor to best visualize the test target. The test target should be placed at 45° to the TV scan lines (Figure 9.17b).

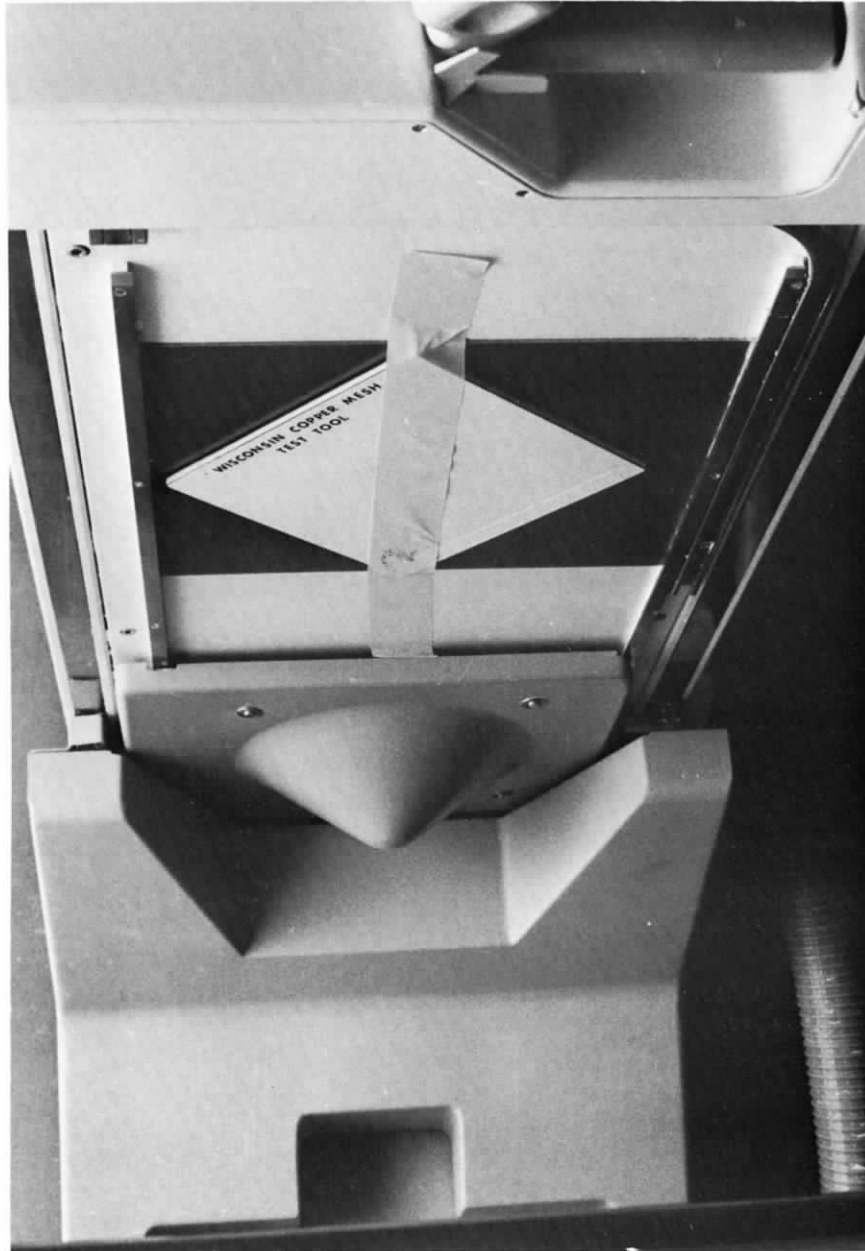


Figure 9.16. Fluoroscopic, photofluorospot film, and cine resolution test setup. The copper wires of the mesh pattern must be oriented at 45° to the television scan lines.

4. Note the finest wire mesh visible in the test target seen in the center and at the edges of the image. Also judge whether the lead numbers appear sharp and whether the entire test target is seen with minimal distortion.
5. Record the results in the QC room log.

**Procedure—Photofluorospot Films and Cine Film**

1. Set the kVp at the lowest level attainable on the system for making photofluorospots. Make three radiographs of the test target.
2. If the imaging system includes a cine system, set the kVp as low as possible and make a cine run of sufficient length to allow the automatic brightness system to stabilize (at least 5 seconds).

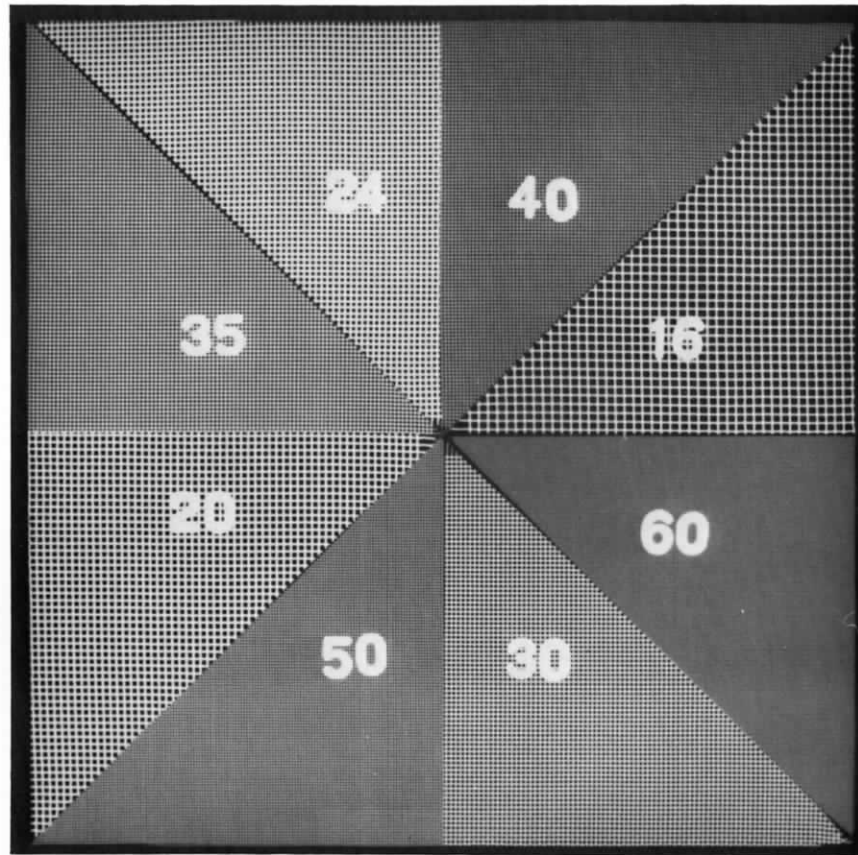


Figure 9.17a. Contact radiograph of fluoroscopic, photofluorospot film, and cine resolution mesh test pattern. The lead numbers indicate the mesh number, or number of wires per inch.

3. Process and view the photofluorospots and the cine film, noting the finest detail visible in the test target seen in the center and at the edges of the image in the films (Figure 9.17c).
4. Record the results in your QC room log.

#### Problems and Pitfalls

This test gives a measure of the information of the total imaging system. The information is subjective and can be influenced by the monitor settings and room lighting as well as the orientation of the test object. Problems noted in the images cannot be readily identified without further testing. However, the results of the PFS films or cinefilm tests may help narrow the search for the cause of the problem, e.g., if the TV resolution is poor, but the photofluorospot resolution is what you would expect, then the TV camera needs refocusing.

#### Acceptance Limits

	Minimum mesh resolutions (mesh/inch)			
	9-inch (23-cm) intensifier		6-inch (15-cm) intensifier	
	Center	Edge	Center	Edge
Optical viewing	40	30	40 +	35 +
Standard TV	20-24	20	30-35	24-30
16-mm cine	35 +	30	40	35 +
35-mm cine and spot films	40	30	40 +	35 +

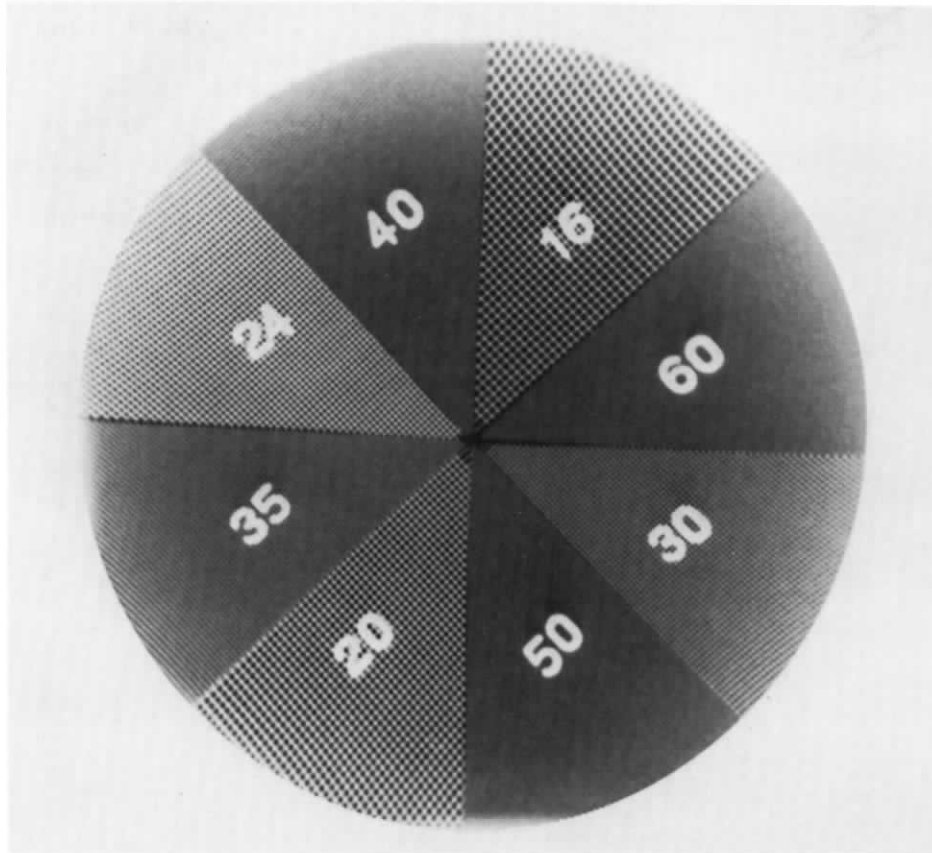


Figure 9.17b. Fluoroscopic image of the mesh test pattern.

#### **Corrective Action**

Evaluation and repair of the system by a qualified service engineer is indicated if the resolution is less than the minimum indicated.

### **9.10. LOW-CONTRAST FLUOROSCOPIC TEST**

#### **Purpose**

To visually check for the ability of the imaging system to display low-contrast information.

#### **Equipment Needed**

Penetrameter consisting of:

1. Two  $\frac{3}{4}$ -inch (2-cm) aluminum plates, 7 × 7 inches (18 × 18 cm)
2. One sheet of 1.0-mm aluminum, 7 × 7 inches (18 × 18 cm), with two sets of four holes of the following sizes: 1.0, 3.0, 5.0, and 7.0 mm ( $\frac{1}{16}$ ,  $\frac{1}{8}$ ,  $\frac{3}{16}$ , and  $\frac{1}{4}$  inch).

#### **Procedure—Televised Fluoroscopic Systems**

1. Place two aluminum plates plus the hole-drilled aluminum sheet on top of the x-ray table. With mobile C-arm equipment, place the phantom directly on the image intensifier face plate (Figure 9.18).

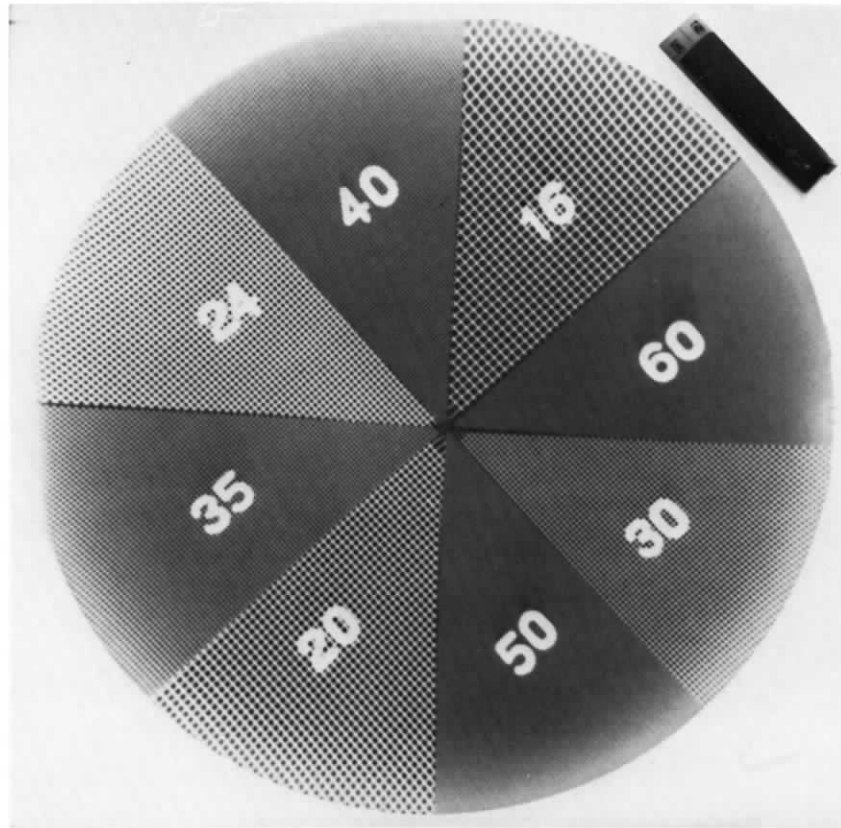


Figure 9.17c. PFS image of mesh test pattern made at the same time as the fluoroscopic image.

2. Set the image intensifier 10 inches (25 cm) above the x-ray tabletop with an undertable x-ray tube system.
3. Allow the automatic brightness system to adjust the fluoroscopic factors and collimate the beam to the test object. The kilovoltage should be in the range of 85 to 90 kVp.
4. View the image on the TV monitor and adjust the contrast and brightness controls to attain the best visualization of the penetrameter holes (Figure 9.19).
5. There are two rows of equally sized and spaced holes. You should see both holes of the same size in order to count them as one hole set. Record the maximum number of hole sets seen.
6. Record the results, including the operating mA and kVp, in the QC room log.

#### Procedure—Mirror-optic Fluoroscopic Systems

1. Place the two aluminum plates plus the hole-drilled aluminum sheet on the x-ray tabletop.
2. Set the image intensifier 10 inches (25 cm) above the x-ray tabletop with undertable x-ray tubes.
3. Collimate the beam and adjust the fluoroscopic factors.
  - a. Collimate the beam to the test object and allow the automatic brightness system to adjust the fluoroscopic factors. The kilovoltage should be in the range of 85–90 kVp.
  - b. If fluoroscopic exposure factors are controlled manually, set the kVp between 85 and 90 and adjust the mA to attain the most pleasing image.
4. There are two linear rows of equally sized and spaced holes. You should see both holes of the same size in order to count them as a hole set. Record the maximum number of hole sets seen.
5. Record the results, including the operating mA and kVp, in the QC room log.

#### Problems and Pitfalls

1. The ability to “see” the penetrameter holes is greatly influenced by the TV monitor settings, as is the ability to “see” detail in routine fluoroscopy.

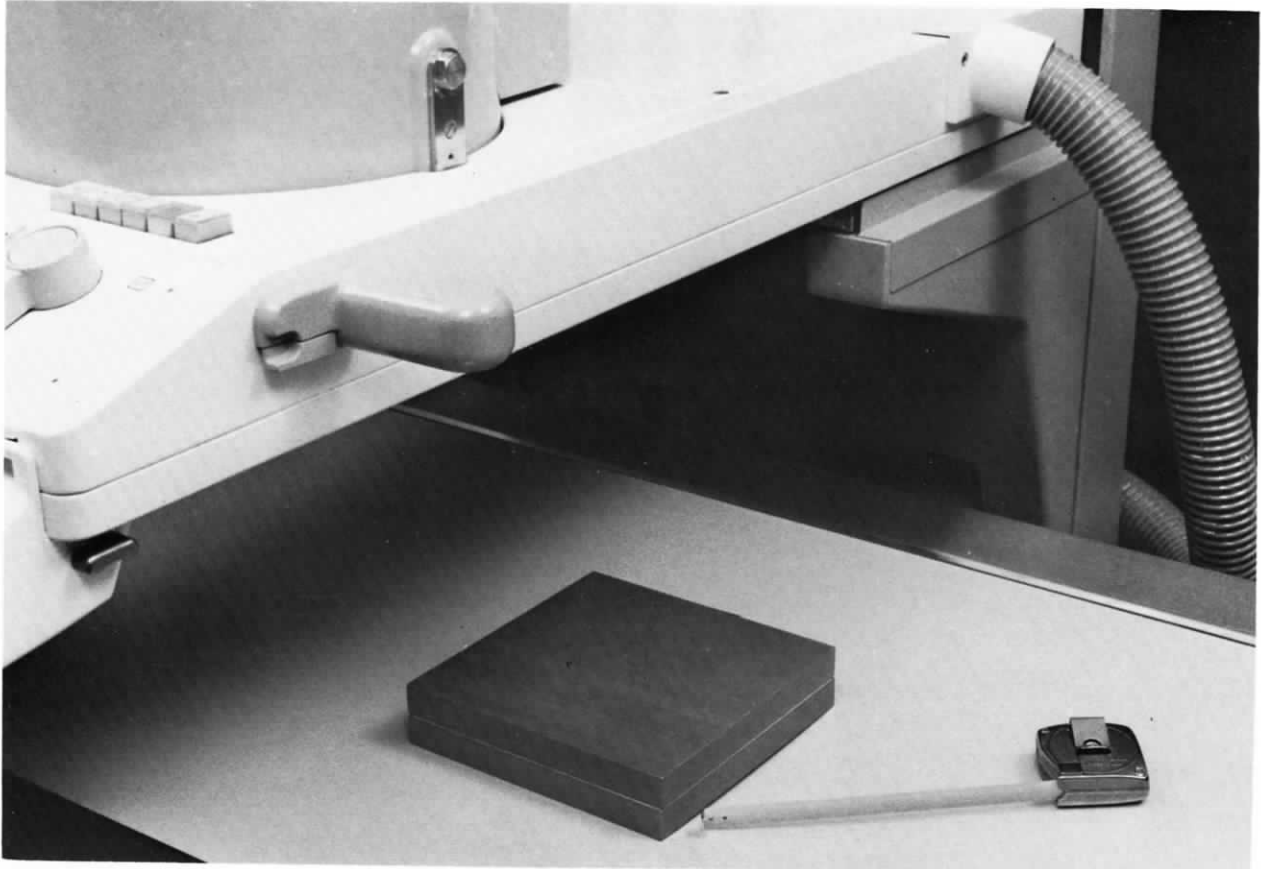


Figure 9.18a. Low-contrast fluoroscopic test setup for undertable x-ray tube.

2. Depending on the usage of your system, the inability to resolve the test holes may be of little consequence. Systems that are not used for chest fluoroscopy or other low-contrast procedures may be unaffected by the lack of low-contrast resolution.

#### **Acceptance Limits**

1. A properly adjusted video system should permit clear visualization of  $\frac{1}{4}$ - and  $\frac{3}{16}$ -inch (7- and 5-mm) holes clearly. The  $\frac{1}{8}$ -inch (3-mm) holes should be just barely visible. With better systems, you may be able to see the  $\frac{1}{16}$ -inch (1-mm) holes clearly.
2. For mirror-optic fluoroscopic systems you should be able to see the  $\frac{1}{4}$ -inch (7-mm) holes, but you will not be able to visualize the smaller holes except on systems of very high quality.

#### **Corrective Action**

Adjustment of the imaging system, kVp, and/or mA by a service engineer is required if the system does not perform properly.

### **9.11. VIDEO WAVEFORM MONITORING**

#### **Purpose**

To assure that the video signal from the fluoroscopic system meets the appropriate standards in terms of voltages and wave shape, and to assure that the system is producing optimum contrast. This will ensure that the TV monitor or tape recorder is receiving an adequate signal and will be able to produce a quality image over the dynamic range of the system.

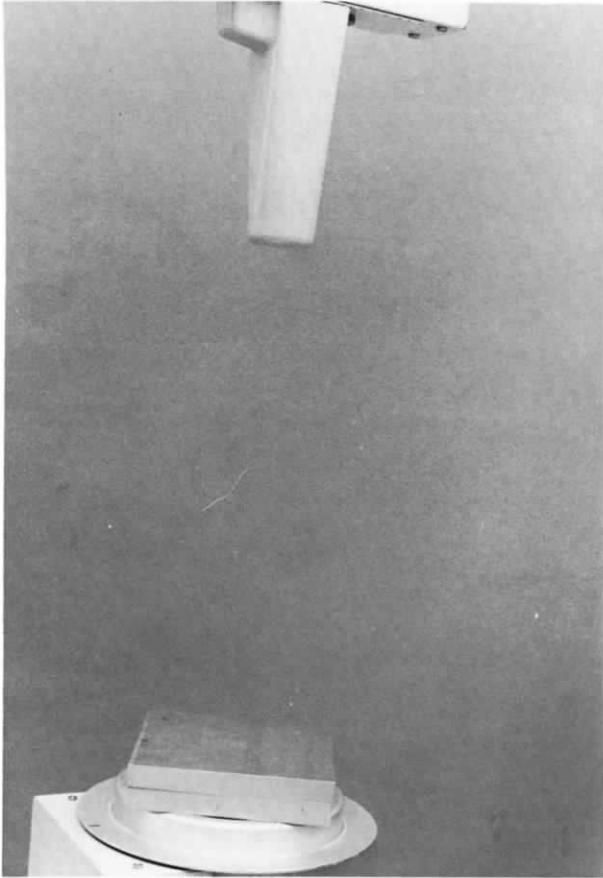


Figure 9.18b. Low-contrast fluoroscopic test setup for C-arm fluoroscopic system.

### Equipment Needed

1. Oscilloscope or video waveform monitor (WFM) [**Note:** A WFM is an instrument similar to an oscilloscope, but it is designed for use in video signal analysis. Although this instrument is used in the broadcast industry, it is not commonly available to radiology service personnel. There are many features of this instrument that make it ideal for testing video systems. However, the major advantage is that you can select and display a single TV line, or any number of TV lines, for analysis. This allows for more precise measurement and a more complete evaluation of video signals.]
2. Oscilloscope camera
3. Patient equivalent phantom (PEP)
4. BNC T connector
5. A 75-ohm termination
6. A  $\frac{1}{8}$ -inch (3 cm) thick lead strip as long as the input phosphor of the image intensifier and 0.1 times its width [e.g., for a 6-inch (15-cm) intensifier, the strip should be 6 inches (15 cm) long and 0.6 inches (1.5 cm) wide]

### Procedure—Video Waveform Voltage and Shape

1. Center the phantom to the image intensifier with the system in the automatic exposure control mode.
2. Disconnect the video cable from the back of the TV monitor and connect this cable to the input of the oscilloscope using the T connector with the 75-ohm termination on one end of the T and the video line on the other end (Figure 9.20). Most systems use the BNC-type connectors; however, there are other types of connectors in use that will require an adapter to connect these with the oscilloscope. An alternate method is to loop through the monitor by connecting a video-quality shielded cable (Teleprompter RG 59 or RG 11, or Belden 8281) from the video output on the back of the monitor to the oscilloscope. This will allow simultaneous viewing of both the monitor and the oscilloscope display. If this approach is used, the termination of the



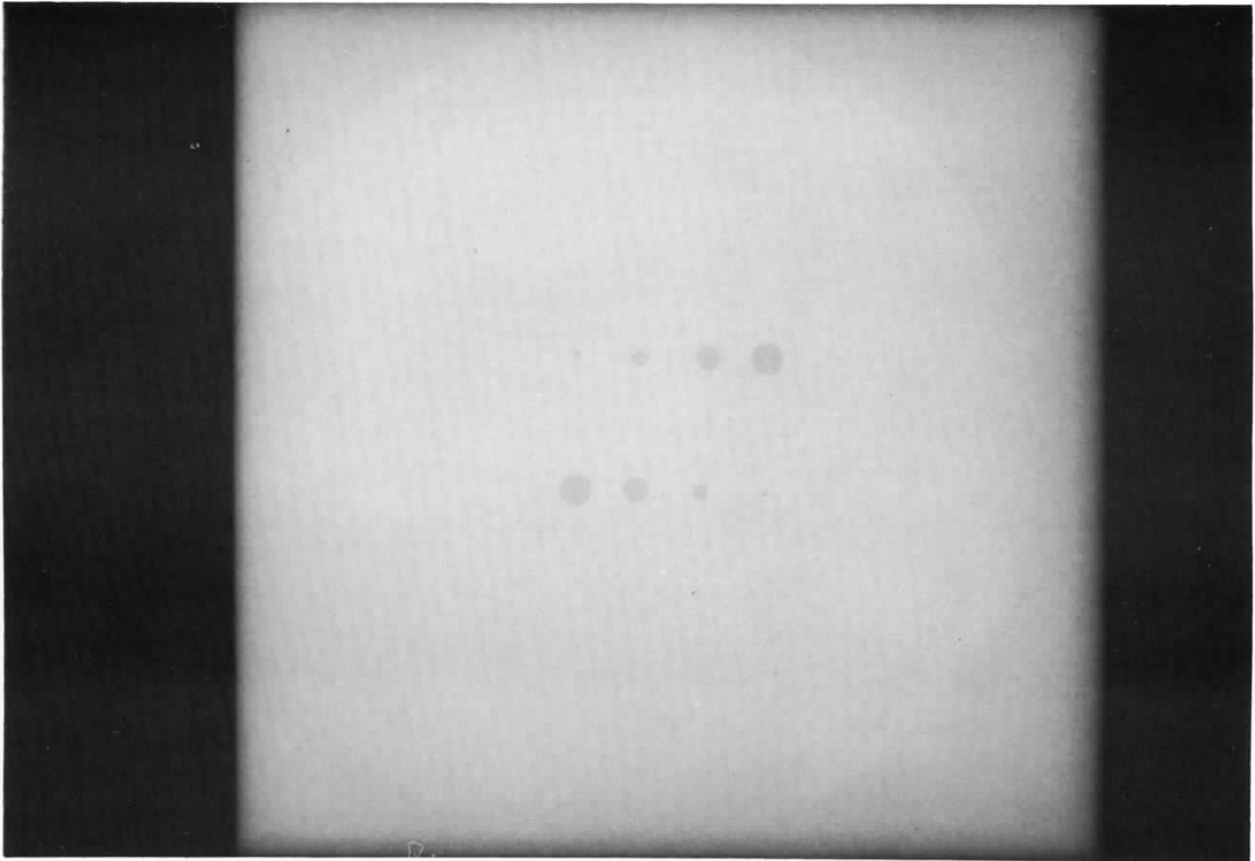


Figure 9.19a. Low-contrast fluoroscopic test results. Contact radiograph of penetrameter showing four low-contrast holes.

monitor must be changed from 75 ohms to high impedance, or 3000 ohms. Failure to change the termination will result in incorrect voltage measurements. Normally, the termination is changed by use of a switch on the back of the TV monitor. However, some systems require removal of the back of the monitor to make the change. If an internal change is required, the loop-through method should not be used.

3. Set the oscilloscope to display 0.2 V per division and 10  $\mu$ sec per division. Adjust the trigger level to obtain a stable image waveform (Figure 9.21).
4. Measure the sync voltage (Figure 9.22a).
5. Measure the black level voltage. (The black level is often referred to as the pedestal or setup voltage.)
6. Determine the time of the black level in the waveform to evaluate the blanking ring size in systems using video blanking. [**Note:** Some systems use an external ring or mask on the face of the monitor.]
7. Observe the shape of the video portion of the waveform, both with and without the fluoroscopic grid in place (Figure 9.22b).
8. Make a picture of the video waveform with the oscilloscope camera. This will serve as a baseline waveform for future comparisons.
9. Measure the peak-to-peak video voltage.

#### **Procedure—Contrast or Flare Measurements**

1. Follow the setup procedure in Steps 1 through 3 above but without the use of the PEP.
2. Adjust the system to operate in the 50–60 kVp range.
3. Tape the lead strip to the center of the input of the image intensifier or the bottom of the spot film device so that the strip is perpendicular to the TV scan lines.
4. Measure the peak white voltage (i.e., the maximum voltage), and the voltage of the image behind the lead strip (Figure 9.22c).

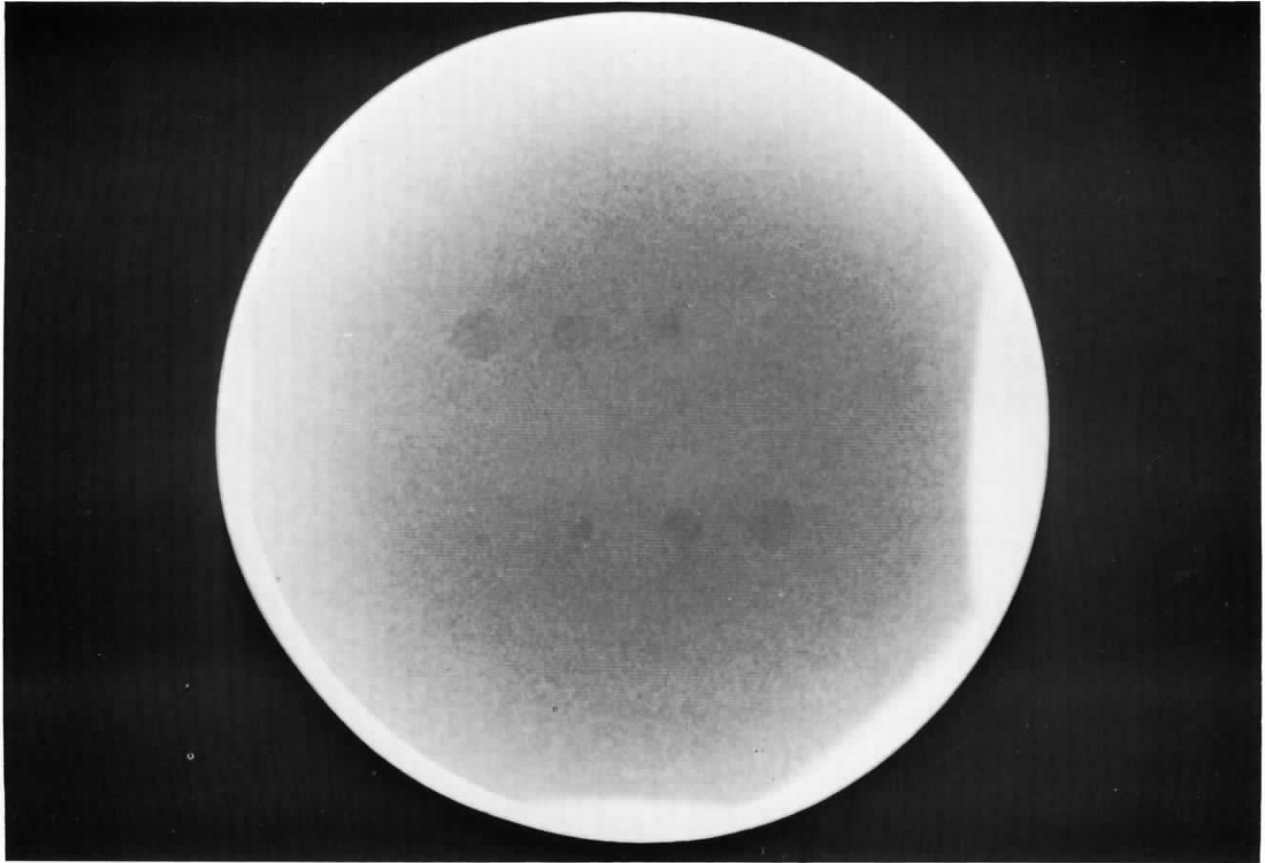


Figure 9.19b. Low-contrast fluoroscopic test results. Fluoroscopic image of the penetrator.

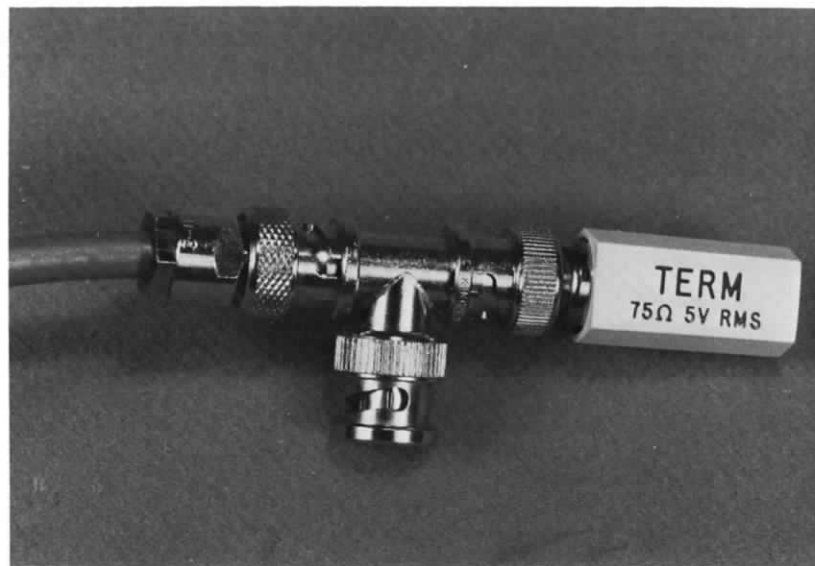


Figure 9.20. Video termination with a "T" connector.

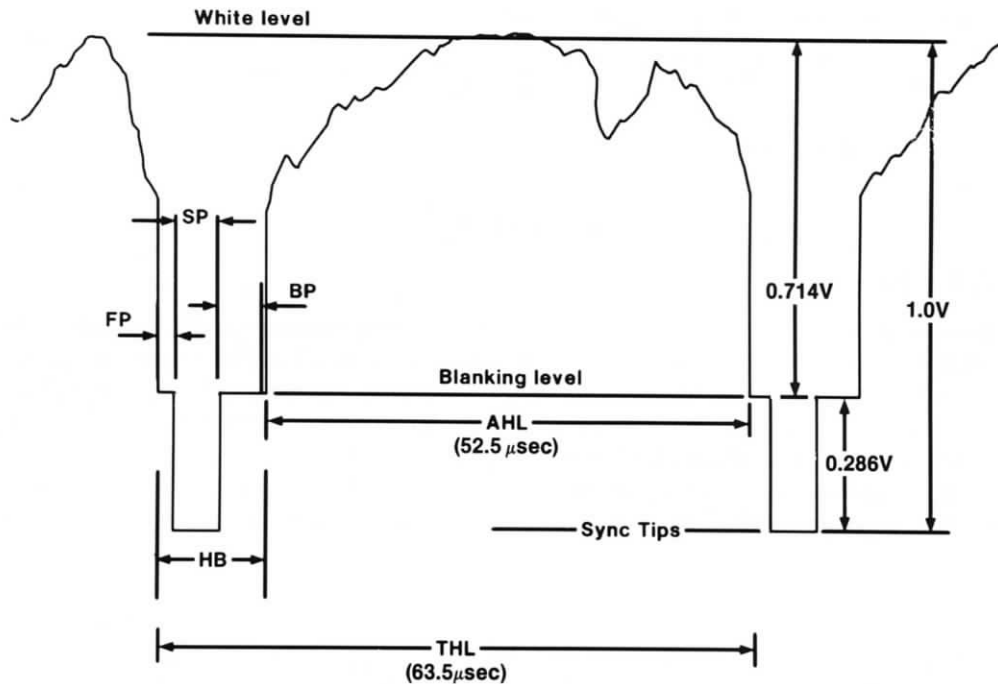


Figure 9.21. Video waveform. This waveform is based on a 525-line, 30-frame per second (60-field per second) video image. [This is a display of video voltage (vertical) as a function of time (horizontal).] The components are as follows: SP—sync pulse, FP—front porch, BP—back porch, HB—horizontal blanking interval, AHL—active horizontal line (that portion of the scan line carrying image information), and THL—total horizontal line.

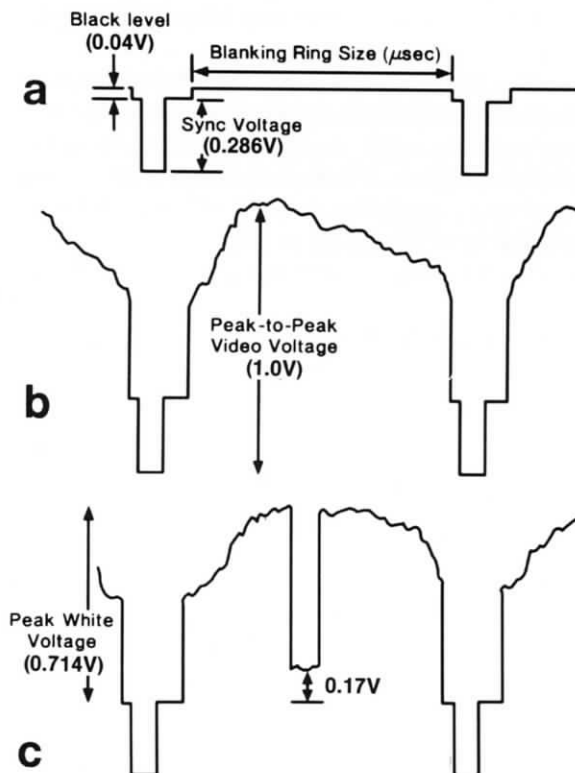


Figure 9.22. Video waveform monitoring test results. (a) Measurement of the sync pulse and black level can be done without a fluoroscopic image, i.e., with no radiation being produced by the x-ray tube. The blanking ring size will always be less than 52.4  $\mu\text{sec}$  (the active horizontal line length) and will probably be between 35 and 40  $\mu\text{sec}$  at its longest point in the center of the TV field or frame. (b) The peak-to-peak video voltage is important, but you must also assure that the sync pulse voltage is correct. This is also an example of a nonuniform waveform, since the dome is not symmetrical about the center of the active horizontal line. This is probably due to grid misalignment. (c) In order to make the flare measurement it is necessary to determine the voltage difference between the peak white and the black level, and the voltage difference between the area behind the lead strip and the black level.

5. Calculate the percentage contrast using the formula

$$\left[ 1 - \left( \frac{\text{Voltage Behind Lead Strip}}{\text{Peak White Voltage}} \right) \right] \times 100\% = \% \text{ Contrast}$$

For example (from Figure 9.22)

$$\left[ 1 - \left( \frac{0.17}{0.714} \right) \right] \times 100\% = 76\%$$

### Problems and Pitfalls

1. Improper termination of any monitor and/or tape recorder connected to the video system will result in incorrect waveform voltage. If all the voltages (sync, black level, and video waveform) appear to be higher or lower than expected, check the termination of each component. Under normal operating conditions, the last component and only the last component of the system must be terminated with a 75-ohm termination. All other components should be terminated with the high-impedance or 3000-ohm termination.
2. In some systems, the video signal is blanked once the signal drops to a predetermined level. In these systems, the black level voltage will not appear and cannot be measured without the assistance of an engineer.

### Acceptance Limits

1. Specification for video signal voltages vary from manufacturer to manufacturer, so it is necessary to consult the service manuals or a service engineer for specifications for your equipment. In general, the sync pulse should be about 0.3 to 0.4 V. [In actuality, all video signals should comply with the EIA Standard RS-170 (Electronics Industries Association, 1957.)]
2. The black level voltage directly affects the contrast of the system and should be not more than 50 mV (0.05 V).
3. Composite video signal (sync plus video) should be between 0.9 and 1.4 V.
4. The blanking rings should measure, dependent on manufacturer, from 35 to 40  $\mu\text{sec}$ . Similar pieces of equipment from the same manufacturer should be within  $\pm 1 \mu\text{sec}$ .
5. The video waveform may vary in shape from unit to unit because of many factors. Some manufacturers use a shading or edge correction circuit that raises the video voltage along the periphery of the image to make up for differences in light output of an image tube over the surface. If an edge correction circuit is used, the waveform will appear flat to dome-shaped across the top of the waveform, or it may even appear depressed in the center if the circuit is overcorrecting. Systems without edge correction circuits will appear dome-shaped and this dome should appear symmetric with a variation from the center to edge of not more than 0.1 V. A change in the shape of the waveform with and without the fluoroscopic grid indicates grid cutoff due to misalignment of the x-ray tube grid combination.
6. Systems with 70% or greater contrast should produce excellent results. Systems with 55–70% contrast should produce acceptable results for general purpose work, but systems with less than 55% contrast are in need of repair or replacement.

### Corrective Action

Discuss your findings with a service engineer. Semi-annual cleaning of the lenses of the TV chain, image intensifier–spot film–camera combination is recommended to prevent loss of contrast.

# 10 **SPECIAL DIAGNOSTIC IMAGING SYSTEMS**

Although the tests in this section are for equipment that may at first seem to have little in common (portable radiographic units, conventional tomographic equipment, and special procedures suites), they are indeed special applications of standard radiographic and fluoroscopic equipment. Each type of equipment presents special problems in everyday use and also presents special problems for quality control tests.

## **PORTABLE RADIOGRAPHIC AND CAPACITOR DISCHARGE UNITS**

Portable radiographic equipment is not just conventional radiographic equipment on wheels. Although they are somewhat scaled down from permanent equipment, portable systems usually lack sophistication in timing circuits and do not have the extensive circuits available that are normally used for calibration purposes. In addition, battery-operated portables, especially those that use the same battery for both radiographic exposures and the power drive system, present special problems in that every use (exposure or movement of the portable unit) reduces the power available. Consequently, subsequent exposures may become lighter unless the unit is recharged frequently.

In capacitor discharge units, the peak kilovoltage drops continuously during the exposure. This means that the peak kilovoltage at the start may be 100 kVp but will drop to 80 kVp at the end of a 20-mAs exposure. [The peak kilovoltage will drop 1 kV for each mAs of exposure in a unit with a 1-microfarad capacitor (Weaver et al., 1978).] Consequently, special attention must be given to building a technique chart using higher kilovoltage and lower mAs than would

normally be used with a conventional generator. If the desired technique is 90 kVp at 20 mAs, then a technique of 100 kVp would be preferred since the average kilovoltage during the exposure would be about 92 kVp.

Portable equipment should meet all acceptance limits described for general radiographic equipment. This is also true for capacitor discharge units except that these units will not be able to meet the kVp requirements. After appropriate calibration by a qualified service engineer, the kVp should be measured by the QC technologist. On future checks, the kVp values obtained for the capacitor discharge units at this initial test should remain constant, or service is required.

## **CONVENTIONAL TOMOGRAPHY**

Conventional tomography, as opposed to computerized tomography (CT), uses the standard techniques of x-ray source and image receptor motion to produce a thin-section image. In addition to all tests carried out on standard radiographic equipment, it is important to evaluate all aspects of the tomographic motion, thickness of cut, and level of cut on a regular basis. It has been our experience that "add-on" tomographic systems require considerably more attention and service at shorter intervals than even the sophisticated, complex motion tomographic units, assuming that the same number of cases is done per day on each.

Tomographic phantoms are relatively expensive but should be purchased if it is necessary to evaluate complex motion tomographic equipment. The simple tomographic test tool (described on pages 62-65)

may be quite adequate for add-on linear motion systems, but the pinhole trace technique described in this chapter should also be used since this provides valuable information concerning the sweep motion of the equipment.

### **ANGIOGRAPHIC EQUIPMENT**

Angiographic or special procedure suites deserve special attention for several reasons. First of all, angiographic equipment is the most sophisticated equipment in most radiology departments (excluding CT). It is necessary to have several interacting components all functioning optimally at the same time, especially in biplane systems. The patients being examined are the most critically ill so equipment failure will have significant consequences, not to mention the normal risk associated with large doses of arterially injected contrast media. The equipment in special procedure rooms is the most expensive in the department, and the cost of personnel to support these rooms is quite high, not to mention the loss of patient revenue if the rooms are out of service for long peri-

ods of time. Finally, the exposures received by patients and staff are the highest in special procedure rooms, especially those with cine systems, because of the limited amount of shielding that can be used and the high dose procedures and long fluoroscopic exposure times encountered.

If a hospital has one special procedures suite, then the cost of a complete set of quality control equipment can easily be justified, based on the cost of the special procedures equipment and operating personnel. Most of these rooms should be completely checked at least monthly, and, ideally, test phantoms should be imaged at the beginning of each case. In addition, the technologist responsible for the rooms should make a complete check of the equipment at the beginning of each day, *before* any patient is placed on the table, to assure that all equipment is functional. This should include not only mechanical checks, but checks of the fluoroscopic system using a phantom and checks of film changers to assure that they are functioning properly and loaded with sufficient film to do a complete study.

# PROCEDURES

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## 10.1. PORTABLE RADIOGRAPHIC AND CAPACITOR DISCHARGE UNITS

### Purpose

To provide consistent, high-quality portable radiographs.

### Equipment Needed

Full complement of QC test tools to check collimator and light field alignment, focal spot size, HVL, kVp, exposure time, and mR/mAs linearity and repeatability as described in the Procedures sections of Chapters 6, 7, and 8

### Procedure—Conventional Portable Generators

1. Perform the full series of tests that you would perform on a fixed radiographic system.
2. Pay special attention to short exposure times such as those used in chest radiography.
3. On single mA station equipment do repeatability studies at a short (1/60–1/30 sec), medium (½ sec), and long (1 sec or over) exposure time.
4. Although not a true linearity, compare the mR/mAs for 3 or 4 time stations.
5. Record the results in the QC room log.

### Procedure—Battery Powered Portables

1. Perform the full series of tests for conventional generator portables.
2. In addition, perform a battery depletion study:
  - a. Completely charge the storage batteries.
  - b. Select an average technique for the day-to-day work load.
  - c. Measure with a dosimeter and record the exposure in mR for three exposures at the preselected technique.
  - d. If your machine has power-assisted motion, drive the machine the typical distance one would travel between patient rooms.
  - e. Repeat the three exposures and movement sequence until the mR output has fallen to 80% of the original output.
  - f. Plot the mR versus the number of exposures on a piece of graph paper (Figure 10.1). If the typical number of exposures per portable run falls short of the number required to reduce the output to the 80% level, you should have little trouble producing consistent-density radiographs if all other radiographic factors are properly controlled.
  - g. If your typical case load goes beyond the 80% mark, recharge the batteries for 5 minutes, and make a measurement of the exposure output. Typically, this brief recharge will bring the generator close to the original output. [**Note:** This brief recharge procedure should be implemented during heavy case load portable outings.]
3. Record the results in the QC room log.

### Procedure—Capacitor Discharge Portable and Permanent Equipment

Perform the series of tests described above for conventional portable generators.

The kVp measurement on capacitor discharge equipment will need special acceptance limits. A typical capacitor discharge unit (1-microfarad capacitor) will lose 1 kVp for each 1 mAs of exposure. In other words, a typical kVp test cassette exposure for 80 kVp would require 20 mAs, and would yield a final minimum of 60 kVp with an average kVp of about 70. To further complicate the issue, the filtration used in the test cassette preferentially attenuates the lower-energy photons, which will yield a kVp reading higher than the average kVp.

### Problems and Pitfalls

1. Portable radiographs of poor quality are often accepted because they are “just portables.” The same performance characteristics can and should be expected from mobile equipment and fixed equipment.

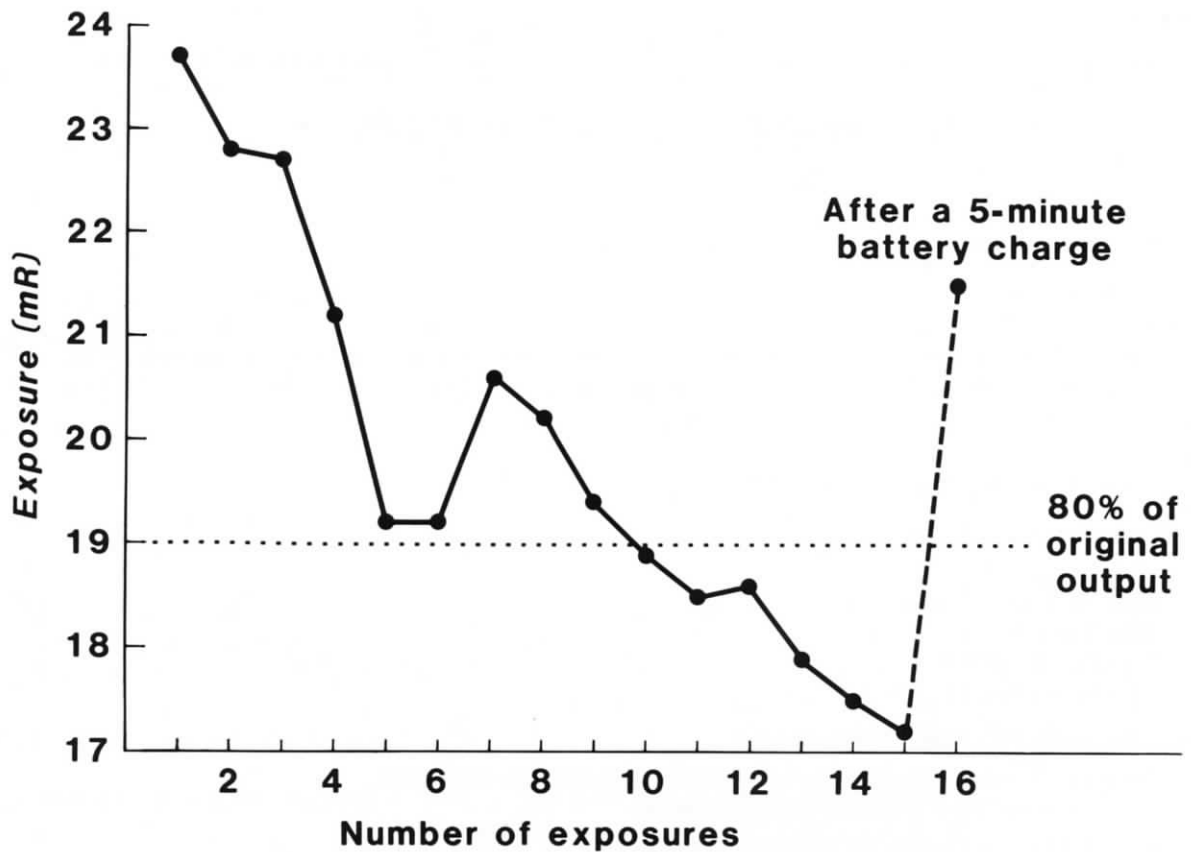


Figure 10.1. Output exposure as a function of the number of exposures for a battery-operated x-ray unit.

2. Special efforts should be made to provide the technologist with every possible aid to assure the correct source-to-image distance, angulation, beam alignment, and exposure factors.
3. Battery-powered portables should be recharged after every use to assure maximum consistency in output, i.e., they should be plugged in and charging at all times when not in use.
4. Capacitor discharge units require special consideration when building technique charts. It is advisable from the patient exposure standpoint to chart higher kVp and lower mAs than you would use for conventional generators.

#### Acceptance Limits

1. Conventional and battery-powered mobile equipment should meet the acceptance limits outlined for fixed equipment.
2. Capacitor discharge equipment should meet all acceptance limits outlined except for the measured kVp. Because there are no calibration curves provided with the kVp test cassette for capacitor discharge equipment, no specific limits can be given, but for an 80-kVp, 20-mAs exposure, expect a 72-74 kVp reading.

#### Corrective Action

If the acceptance limits are not met, have a service engineer correct the problems.

## 10.2. TOMOGRAPHY

### Purpose

To assure maximum resolution in planes of interest and optimum blur of overlying structures, and that the patient entrance exposures are the same from room to room.



## Equipment Needed

1. Tomographic phantom [commercially available, typically consists of varying-size mesh resolution patterns and lead numbers to indicate slice level and thickness (Figure 10.2)]
2. A  $4 \times 4 \times \frac{1}{8}$ -inch ( $10 \times 10 \times 0.3$ -cm) sheet of lead with a  $\frac{1}{16}$ -inch (1.5-mm) countersunk pinhole in the center
3. Direct readout dosimeter

## Procedure

1. Place the phantom and the lead pinhole on the table (Figure 10.3). [**Note:** For linear tomographic equipment turn the phantom so the lines of the mesh pattern are at  $45^\circ$  to the direction of the tube travel.]
2. Adjust the fulcrum to the appropriate level for the phantom being used. The pinhole should *not* be at the same level as the cut level. It should be about 2 cm above that level.
3. Set the arc to the maximum routinely used. Make sure the exposure time is long enough to cover the complete arc.
4. Cover the phantom, but not the pinhole, with a sheet of lead.
5. With the x-ray tube centered and perpendicular to the film, make a nontomographic exposure at the same kVp and about 10% of the mAs needed to properly expose the phantom. This exposure will mark the center of the pinhole trace.
6. Remove the lead, zero the dosimeter, and make a tomographic exposure of the phantom and the pinhole; read the exposure from the dosimeter. [**Note:** Depending on the phantom thickness, the pinhole trace may be too dark to interpret. An ideal density would be 0.6 to 1.2, and can be achieved by placing several millimeters of the aluminum used to measure the HVL over the pinhole.]
7. Repeat the procedure in the opposite direction for linear tomographic equipment that exposes in both directions.
8. The maximum arc should show any problems, if they exist, but if you wish to evaluate the slice thickness for lesser tomographic arcs repeat the procedure at the desired arc.
9. Interpretation
  - a. Slice level—For the typical commercial type, read the lead number that is in best focus (Figure 10.4).
  - b. Slice thickness—Observe the total number of lead numbers in focus.
  - c. Resolution
    - i. Observe the finest mesh size resolved (typically #30 to #50 mesh is present in most phantoms).
    - ii. Compare films with films from a similar tomographic unit or with ones taken previously on the same equipment.

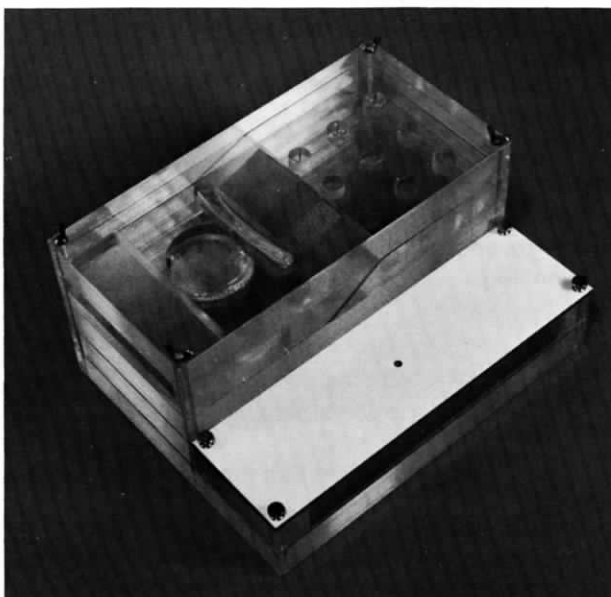


Figure 10.2a. A tomographic phantom developed for our quality control program that allows all sections to be imaged at one time, and allows for a pinhole trace to be made at the same time as the tomographic image.

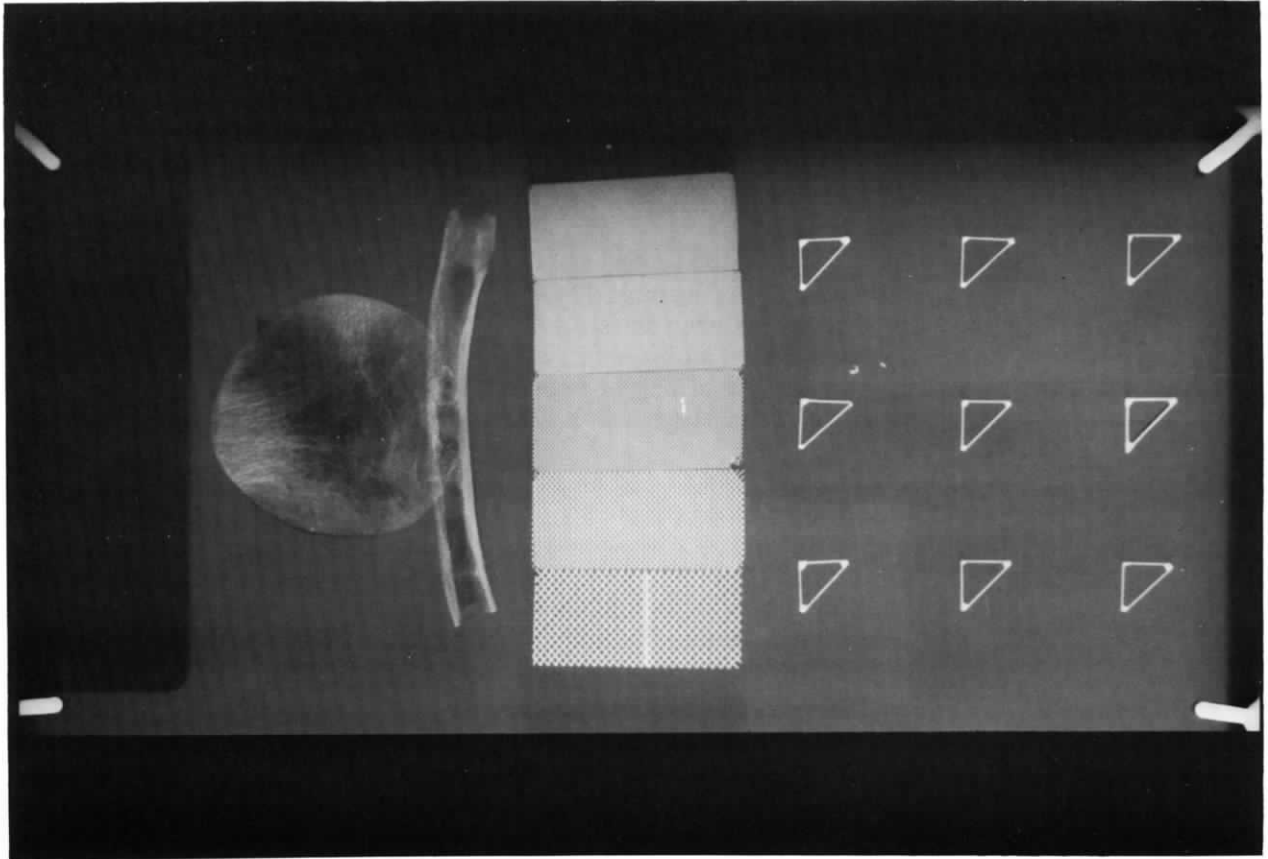


Figure 10.2b. Radiograph of tomographic phantom shown in a. A portion of the femur lies in the plane of the tomographic cut with the rib lying above the plane. The mesh patterns lie at an angle through the plane of cut. A cutout for identification information (dark area on the left) lies in the plane of cut. The small triangles also lie in, above, and below the plane of cut, but are separated by 1 mm.

- d. Pinhole trace
    - i. For linear tomography the pinhole trace should be equally divided on either side of the center mark.
    - ii. Check any excessive change in density over the length of the trace. Areas of increased and decreased density will indicate hesitation or changes in the speed of the tomographic sweep.
  - e. Blur
    - i. Observe the edges of the resolution mesh or the lead numbers out of the plane of focus for smoothness of blur.
    - ii. It may be helpful to place a paper clip bent into the shape of a triangle on top of the phantom, with one edge of the triangle parallel to the direction of the tomographic sweep. This arrangement will give an indication of the blur for objects parallel,  $45^\circ$  to, and  $90^\circ$  to the direction of travel.
10. Record the results and the dosimeter reading in the QC room log.

#### Problems and Pitfalls

1. Some linear units may produce better results in one direction of travel than the other. Make sure to test in both directions of travel. If efforts to correct the problem fail, establish a procedure to have all tomographic exams done in the direction that produces the best results.
2. Pay special attention to the blur capability of the tomographic unit. A phantom film may give the appearance of a properly functioning machine, but if the blur is poor, the results will be less than adequate.
3. When comparing resolution between different machines (using the same screen-film combination) keep in mind that different-size focal spots will have an effect on resolution.

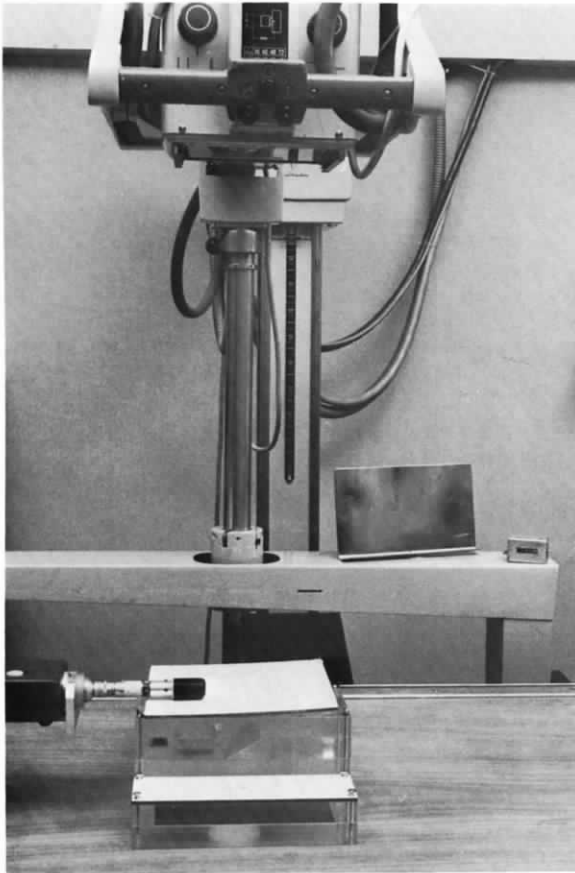


Figure 10.3a. Tomographic test setup. A light exposure is first made (with lead over the imaging portion of the phantom) with the tube in the center position so that a pinhole image is produced marking the center of the sweep.

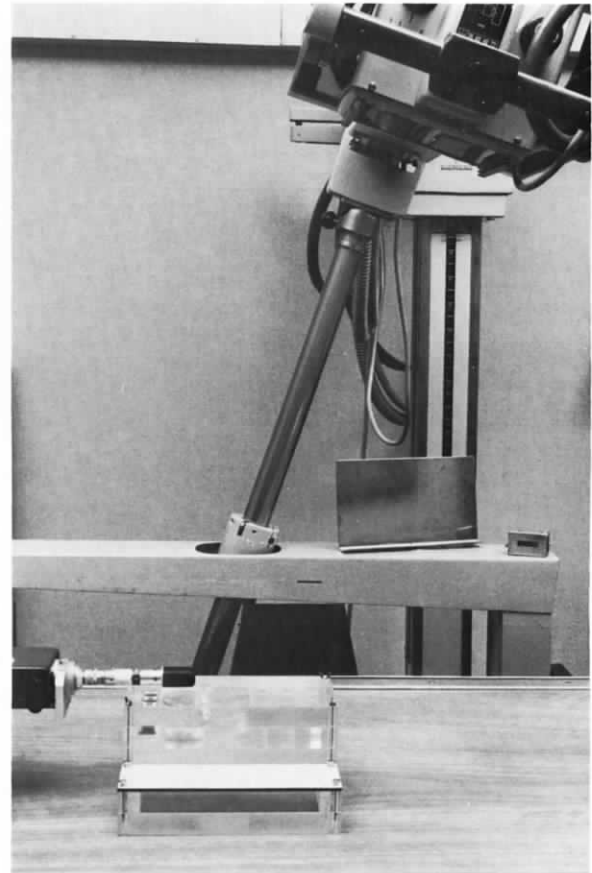


Figure 10.3b. Tomographic test setup. A conventional tomographic exposure is then made so that both pinhole images and a tomographic image of the thick section are made at the same time.

4. The dosimeter must be located in the same position relative to the anode-cathode axis (parallel and perpendicular) for consistent results. Also, the dosimeter should be placed such that it will be exposed to radiation during the entire tomographic sweep.

#### Acceptance Limits

1. The slice level should be within 5 mm of the indicated level.
2. The slice thickness varies with arc, but a linear sweep with a 30° arc should have a slice thickness of 2 to 2.5 mm. A complex motion tomographic unit operating in excess of 30° of arc should have a slice thickness of about 1 mm.
3. The resolution will be dependent on the focal spot size, the magnification (phantom thickness), and the smoothness of the tomographic motion. A good-quality unit will resolve the finest mesh (#50 mesh). A typical linear tomographic unit should resolve the #40 mesh. A unit that can resolve only the coarsest mesh size (#20 or #30) is in need of repairs.
4. The pinhole trace for a linear unit should be equally divided on either side of the center mark. If it is not, check to see that the correct exposure time was used. Complex motion units should not leave large gaps or greatly overlap on the trace pattern. The density of the trace should be relatively smooth and follow a smooth, uniform course (Figure 10.5).
5. The blur of objects out of the plane of focus should be smooth and not a series of repeating images of the object.



Figure 10.4. Commercially available tomographic phantom. This phantom requires several exposures to obtain the necessary information.

6. For similar tomographic systems using similar generators, tubes, collimators, tabletops, and screen-film combinations the entrance exposures to the phantom should be within  $\pm 10\%$  of each other. If there is a greater variation, then you should investigate the cause, paying particular attention to the HVL, the output of the x-ray tube, and any other factors that may affect the exposure to the patient. If rooms do not use similar equipment, then exposure variations will be greater than noted above. However, you should investigate the reason for these variations and consider differences in the tabletops, HVLs, collimator design, x-ray tubes, and any other factors that may affect the output of the x-ray generator and the patient exposure. Measurements of the PEP for Bucky uniformity and motion and of the exposure consistency (pages 89–90) should also be made. With these measurements, you can compare entrance exposures in the room under two different conditions.

#### Corrective Action

1. Observe the motion of the x-ray tube and film tray for hesitation or adverse motion. If adverse motion is seen or indicated on the pinhole trace, try to locate and correct the cause of the problem.
2. Clean any dirt from the tube and Bucky tracks or support rails.
3. Tighten any loose screws, bolts, or connecting pins.
4. Look for loose or worn bearings.
5. Make sure the tube and film tray locks are releasing during the tomographic motion.
6. Correct the exposure time and check position-sensing microswitches if the pinhole trace is not equal on either side of the center.
7. Consult a qualified service engineer if your efforts fail to correct the problem.

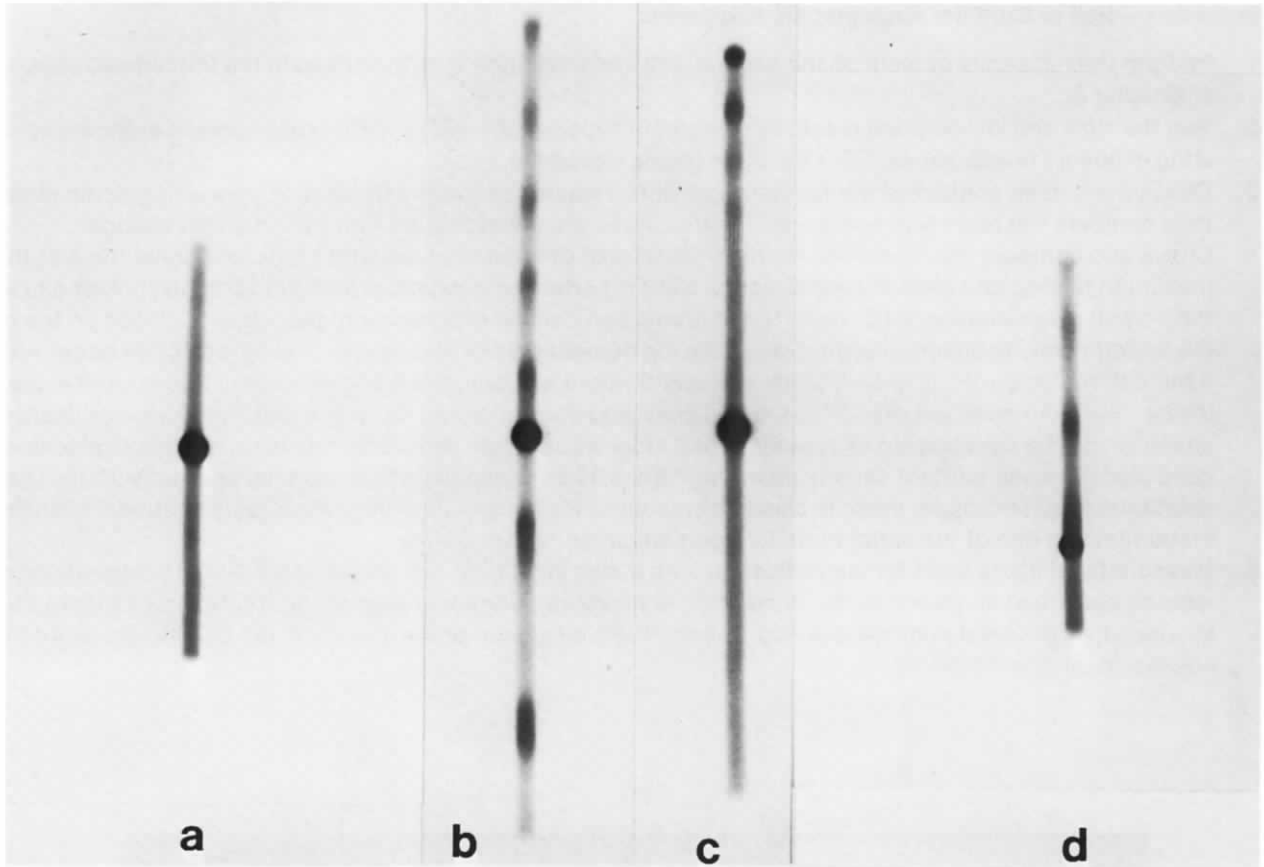


Figure 10.5. Pinhole traces. **(a)** Good pinhole trace with image located symmetrically on either side of center mark. **(b)** Unacceptable motion, probably due to dirt or lack of lubrication on the rails of the tube and cassette system. **(c)** Note the heavy exposure at the top end of the trace. This could be due to either the tube not starting to move before the x-ray exposure is initiated or the tube motion terminating before the exposure terminates. **(d)** In addition to poor motion this exposure was not symmetric about the center mark. This may be due to the x-ray exposure time terminating the exposure before the entire tomographic swing has been completed.

### 10.3. ANGIOGRAPHIC EQUIPMENT

#### Purpose

To assure optimum-quality angiographic examinations.

#### Equipment Needed

1. A full complement of test tools to check collimator alignment, focal spot size, HVL, kVp, exposure time, mR/mAs linearity, and repeatability
2. Star focal spot test target (for focal spots of 0.3 mm or less)
3. Copper mesh resolution test tool, and a low-contrast resolution test tool to check fluoroscopic and cine resolution
4. Lead resolution target
5. Screen contact test mesh
6. A homogeneous patient equivalent phantom (PEP)
7. Direct readout dosimeter

### Procedure—Roll or Cut-Film Angiographic Equipment

1. Perform the full series of tests on the generator(s) and x-ray tube(s) as described in the Procedures section of Chapter 8.
2. Test the high- and low-contrast resolution parameters (pages 150–155) and the maximum and standard operating exposure levels (pages 133–138) of the image intensifier.
3. Check the screen contact of the film changer at the maximum frame rate used in your angiographic suite, then compare the rapid film contact test with a static (single-exposure) film from the film changer.
4. Check and compare the resolution (with a phantom) of the film changer with static and serial films at the maximum filming rate used. If magnification work is performed check the resolution both in contact and at the normal magnification ratio used. The phantom can consist of a variety of test objects placed on top of the uniform density phantom used to measure the fluoroscopic exposure rate. A lead resolution target with a bar pattern that goes to 5 cycles/mm or beyond would be ideal, but a copper mesh pattern can be used [Note: Turn the mesh pattern 45° to the grid lines, and the lead target 90° to the grid lines.] A magnification phantom can be constructed of loosely bound steel wool, small catheters, fine wire, and small pieces of bone placed on the uniform density phantom (Figure 10.6). These objects could also be used with the lead resolution target or copper mesh to check the resolution in contact (non-magnification) situations. Save the static film and one of the serial films for comparison on return checks.
5. Measure focal spots used for magnification with a star focal spot test target at a 3:1 or 4:1 magnification ratio as described on pages 79–80. In addition to measuring the focal spot at the NEMA-specified mA and kVp (one-half the maximum mA and kVp), measure the focal spot at the maximum mA used to check for excessive focal spot blooming.

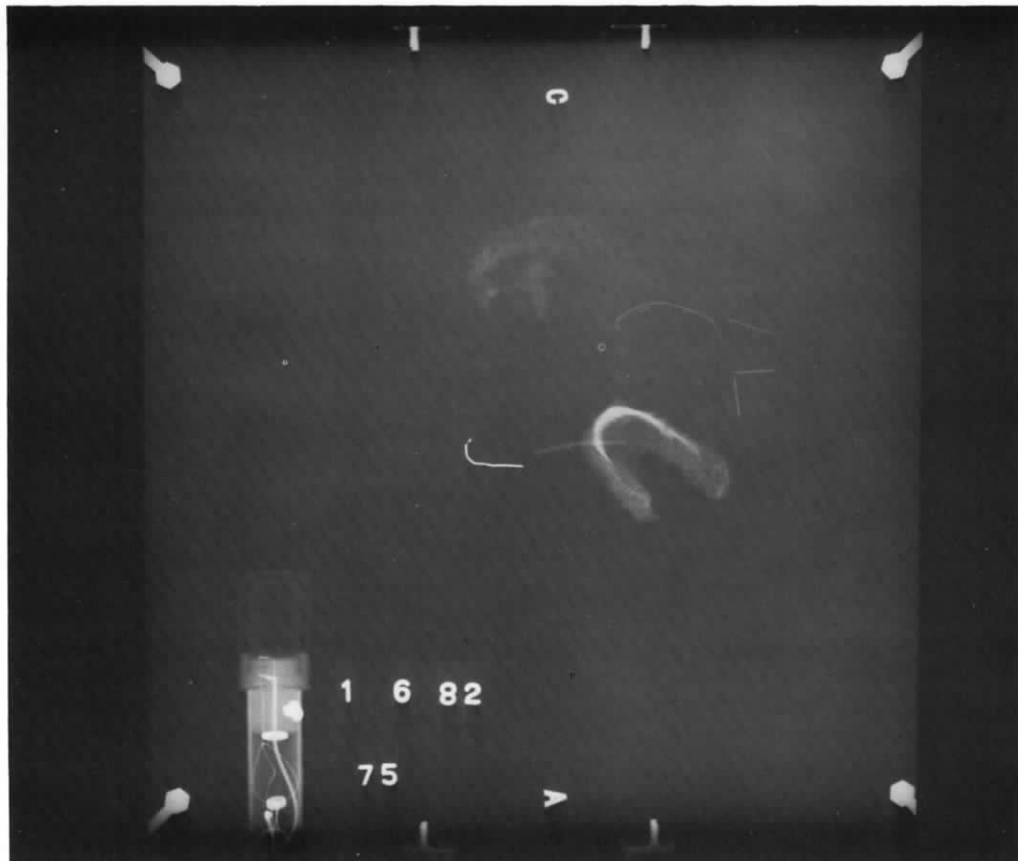


Figure 10.6. Radiograph of PEP with objects added that are common in the angiographic environment.

### Problems and Pitfalls

1. An angiographic suite consists of many key components that can greatly affect the quality of the final product. Each component must be thoroughly tested on a regular basis.
2. Some film changers are not capable of producing good-quality angiograms at a high frame rate, because of either poor design or excessive wear. Check them at all frame rates normally used, and use the frame rate that produces the best results whenever possible.
3. Focal spots that have excessive bloom and produce less than adequate images are not covered under any manufacturer's warranty. Situations like this must be handled on a one-to-one basis with the vendor.

### Acceptance Limits

1. Generators, x-ray tubes, and fluoroscopic systems should meet acceptance limits outlined in the respective Procedures sections of Chapters 7, 8, and 9.
2. Film changer screen contact may deteriorate somewhat on the outside edges of the image during serial runs because of the lack of adjustment points at the very edge of the pressure plates, but the center contact must be uniform throughout. If the contact problems cannot be corrected because of poor design or excessive wear, try to limit the use to the slowest possible frame rate.
3. Resolution loss due to serial motion should be minimal—up to 6 frames/sec on a good quality film changer. You may lose one group of bars (approximately 0.2 to 0.3 cycle/mm) on a lead resolution target, and you should not lose a full mesh size if a copper mesh pattern is used.

### Corrective Action

1. If you experience excessive resolution loss, check for vibration, film movement during exposure, or changer motion that could cause blurring of the image. If none can be found consult a service engineer.
2. For generators or x-ray tube problems consult a service engineer.

### Procedure—Cine Systems

1. Check the fluoroscopic maximum and standard exposure rate as outlined on pages 133–138.
2. In addition, regularly check the standard cine exposure rate following the same procedure outlined on pages 146–150. Clearly outline all the parameters, such as tower height, collimation, frame rate, and selected kVp, so this procedure can be easily duplicated on return checks. The ideal time to start this program would be just after a service engineer has calibrated the system. The typical method of setting the exposure rate is to remove the grid from the face of the image intensifier and then set the entrance exposure rate through an attenuator to the input phosphor to approximately 18 to 20  $\mu\text{R}/\text{frame}$  or 70 mR/min.
3. Regularly check the high- and low-contrast resolution of the cine system as described on pages 150–155.
4. Check and record the film density produced by the cine system by reading the density from a low-contrast test target or from a cardiovascular phantom if one is available.
5. A simple phantom and patient identification marker can be constructed from inexpensive materials that can provide a continuous check of a cine system performance (Figure 10.7). This phantom can be used to identify the patient before each case and will continuously give an indication of any changes in resolution and contrast. The attenuator can be copper (best) or aluminum. A small step wedge (3 or 4 steps) can be made out of lead foil, such as the lead backing in a cassette or the lead in a dental film back. Steps with 1, 2, 4, and 8 thickness of lead foil from a dental pack can be used. Copper screen can be used for a simple resolution pattern. [**Note:** Check with a local hardware dealer for copper screen mesh.] The date and the patient's identification number can be placed on the phantom with lead numbers.
6. With the assistance of a service engineer set up a program to clean the lenses of the image amplifier and cine camera every 6 months. Excessive dust and dirt can greatly reduce the contrast of a system.
7. Set up a program to clean the viewing screen and lenses of your cine projector monthly.

### Problems and Pitfalls

Cine systems are complex systems that have more stringent requirements than most radiographic equipment. Work closely with the manufacturer of your equipment to learn these requirements, and establish a quality control program that meets the needs of your equipment.

### Acceptance Limits

1. The standard cine exposure rate is dependent on many factors, such as the frame rate, kVp, filtration, and exposure requirements of your image amplifier. A change of 1  $\mu\text{R}/\text{frame}$  at the entrance to the image inten-

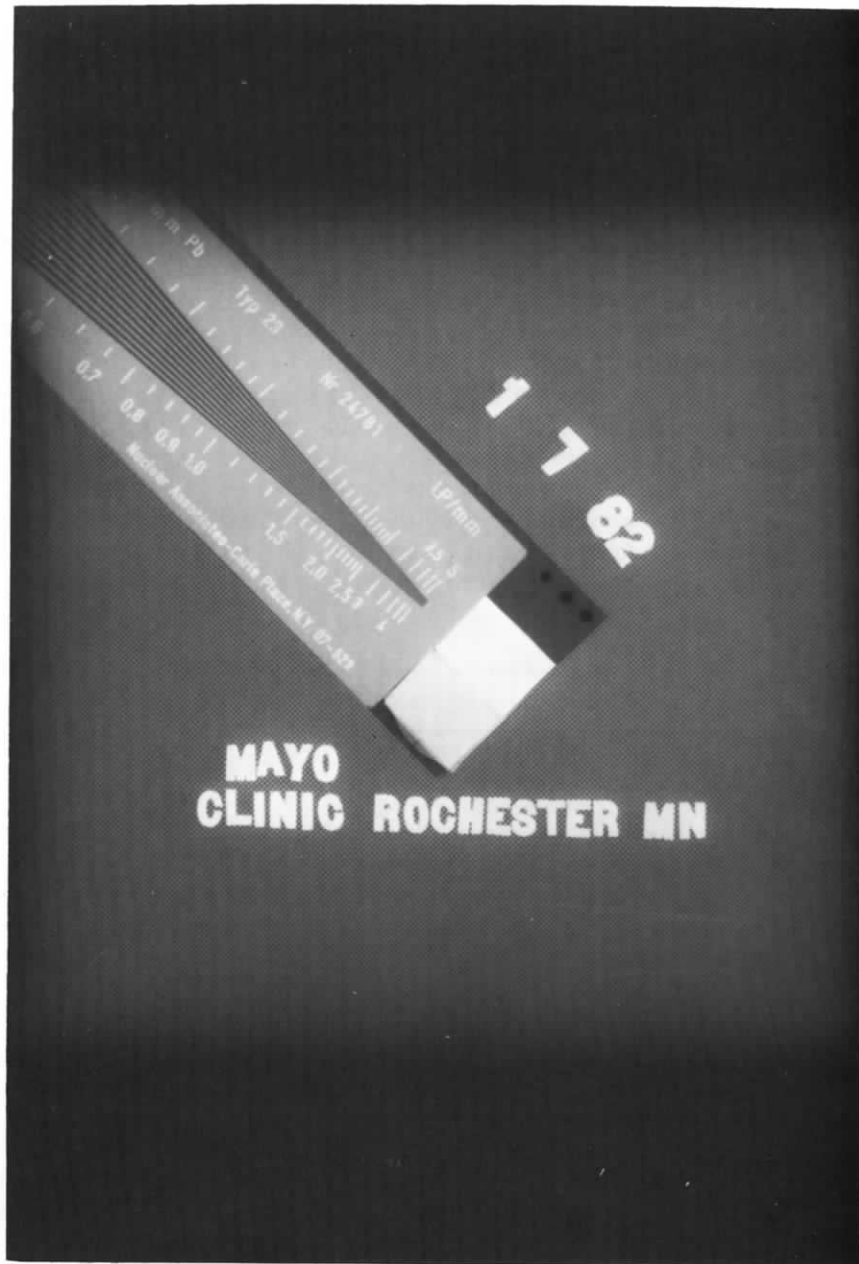


Figure 10.7a. Contact radiograph of the cine patient identification and test phantom. Patient ID information is added to this phantom and it is imaged before each patient is placed on the table for an examination.

sifier can mean a difference of several R/min at the entrance to a 21-cm patient equivalent phantom. You will have to establish acceptance limits that meet the needs of your equipment. To give you some idea of the magnitude of the entrance exposure rate, our equipment at 60 frames per second in the 6-inch (15-cm) mode operates at about 70–75 R/min through a 21-cm patient equivalent phantom (at 70 kVp).

2. A good-quality cine system will be able to easily resolve # 60 mesh in the center of the image. If a lead resolution target is used expect to resolve 2 cycles/mm or better. The low-contrast resolution test should resolve the smallest hole size [ $1/16$  inch (1.5 mm)].
3. The typical film density range selected is from 0.80 to 1.2 (these are not control limits).



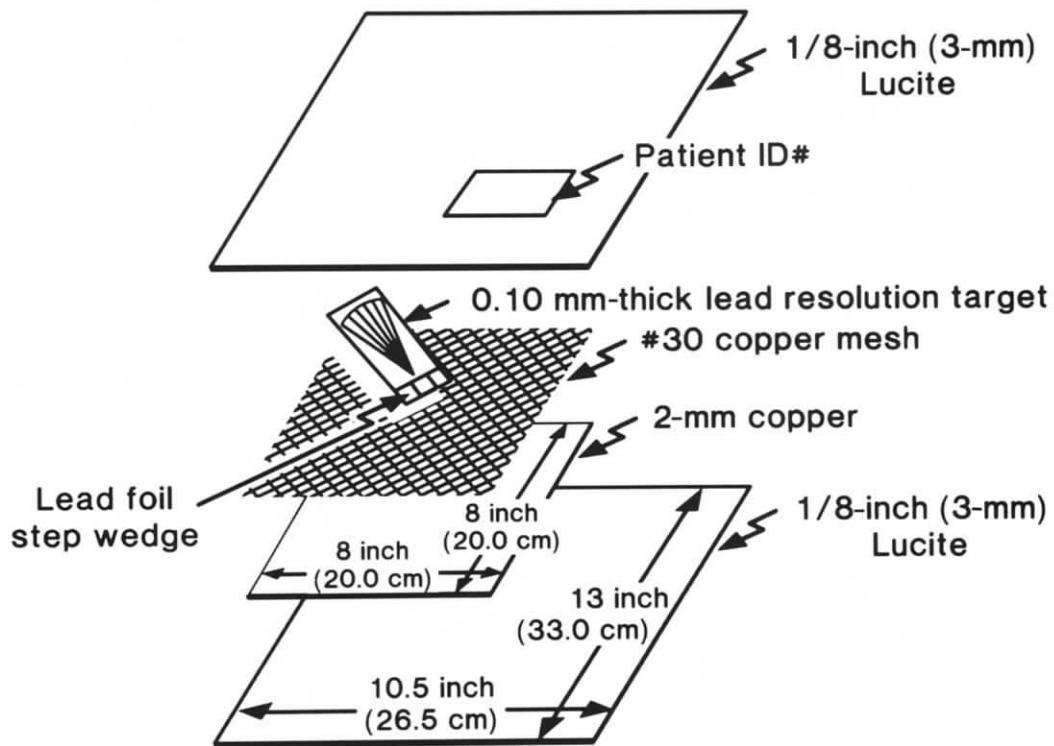


Figure 10.7b. Sketch of the cine patient identification and test phantom.

**Corrective Action**

1. Carefully follow the manufacturer's maintenance schedule and particularly the cine camera film loading and maintenance instructions.
2. For exposure rate or resolution problems consult a qualified service engineer.